United States Patent [19]

Tanaka et al.

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[45] **Date of Patent:** **Mar. 6, 1990**

[54] **DIRECTIONAL COUPLER DEVICE**

[75] Inventors: **Toshiaki Tanaka,** Yokosuka; **Masayoshi Aikawa,** Takarazuka, both of Japan

[73] Assignee: **ATR Optical and Radio Communications Research Laboratories,** Kyoto, Japan

[21] Appl. No.: **254,499**

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[86] PCT No.: **PCT/JP88/00526**

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§ 102(e) Date: **Aug. 31, 1988**

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PCT Pub. Date: **Dec. 1, 1988**

[30] **Foreign Application Priority Data**

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Aug. 13, 1987 [JP] Japan 62-203309
Aug. 17, 1987 [JP] Japan 62-203676

[51] **Int. Cl.**⁴ **H01P 5/18**
[52] **U.S. Cl.** **333/116;** 330/295
[58] **Field of Search** 333/109, 116; 330/286, 330/295

[56] **References Cited**

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Primary Examiner—Paul Gensler
Attorney, Agent, or Firm—Birch, Stewart, Kolasch & Birch

[57] **ABSTRACT**

The present invention relates to a multi terminal directional coupler combined by a plurality of directional couplers. Two directional coupling conductors form each of the directional couplers and are provided on both side faces of a ground conductor through dielectric substrates so as to oppose each other. Openings are defined on the ground conductor corresponding to the coupling conductors so that the coupling conductors are electrically coupled through the openings. Therefore, interference between transmission lines situated on both sides of the ground conductor can be prevented and the multi terminal directional coupler can be made small in size and weight.

6 Claims, 24 Drawing Sheets

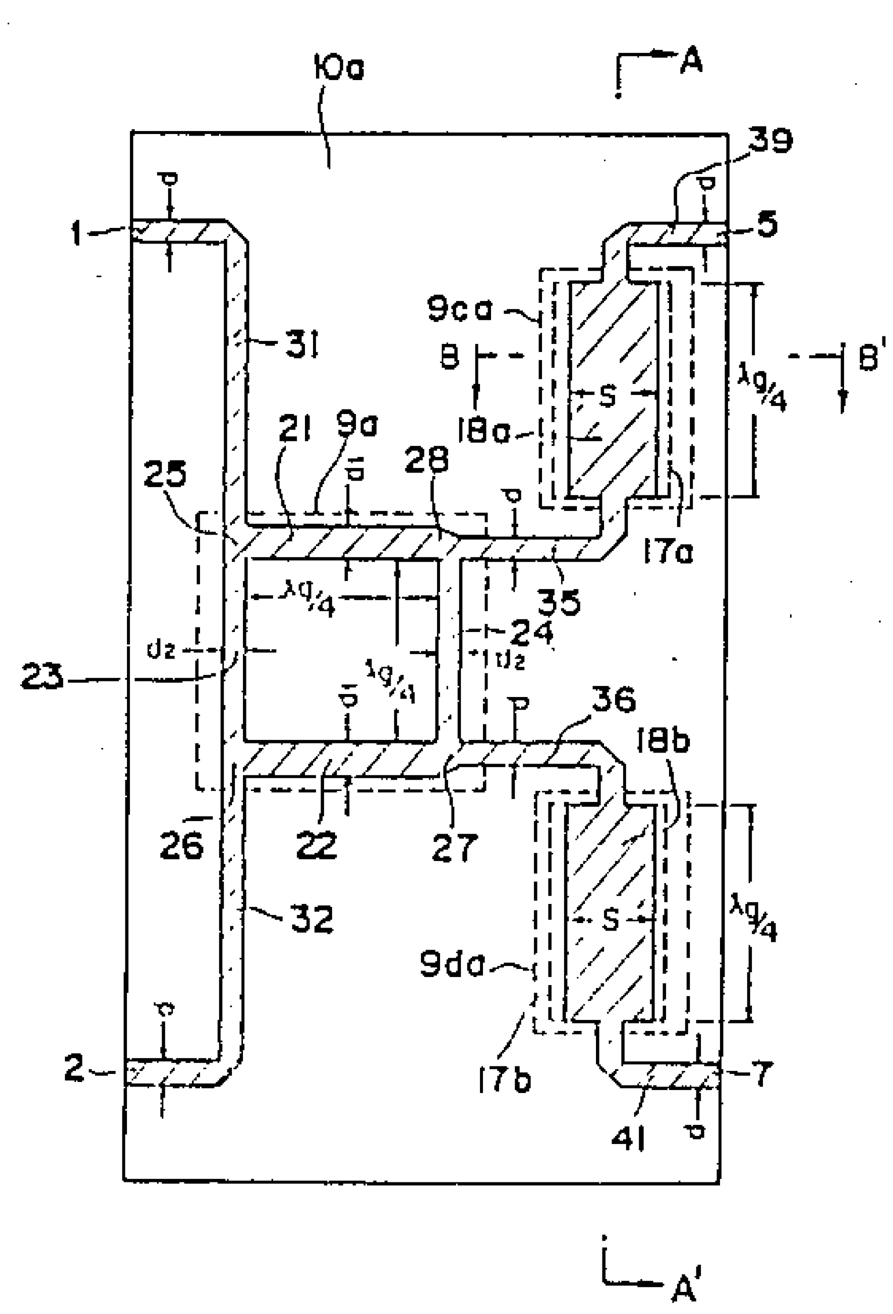
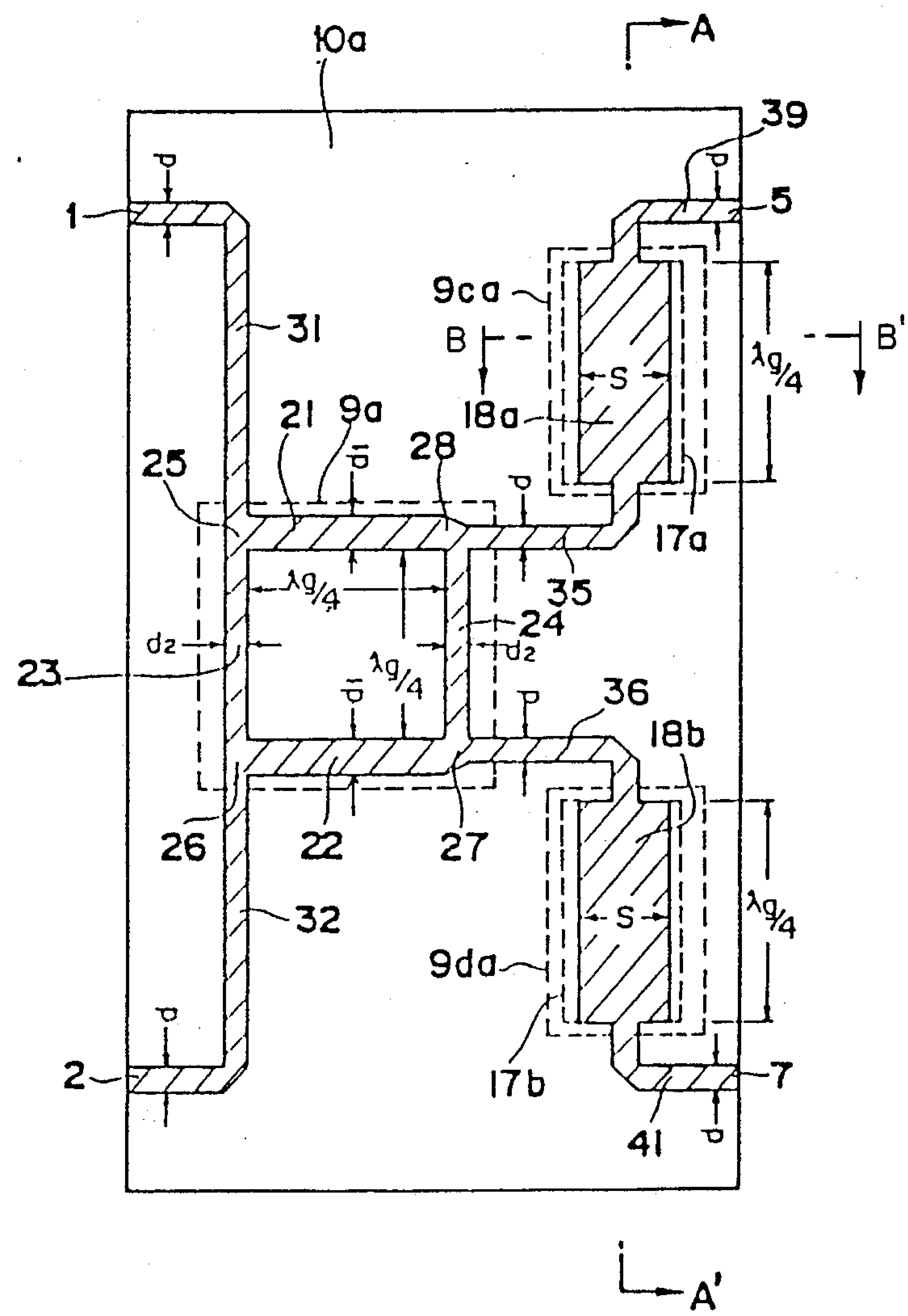


Fig. 1 (A)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A
39
5
1
31
9ca
B
B'
S
$\lambda g/4$
18a
21
9a
28
25
17a
35
$\lambda g/4$
24
d2
23
$\lambda g/4$
36
18b
26
22
27
32
S
$\lambda g/4$
9da
17b
2
7
41
A'

Fig. 1 (B)

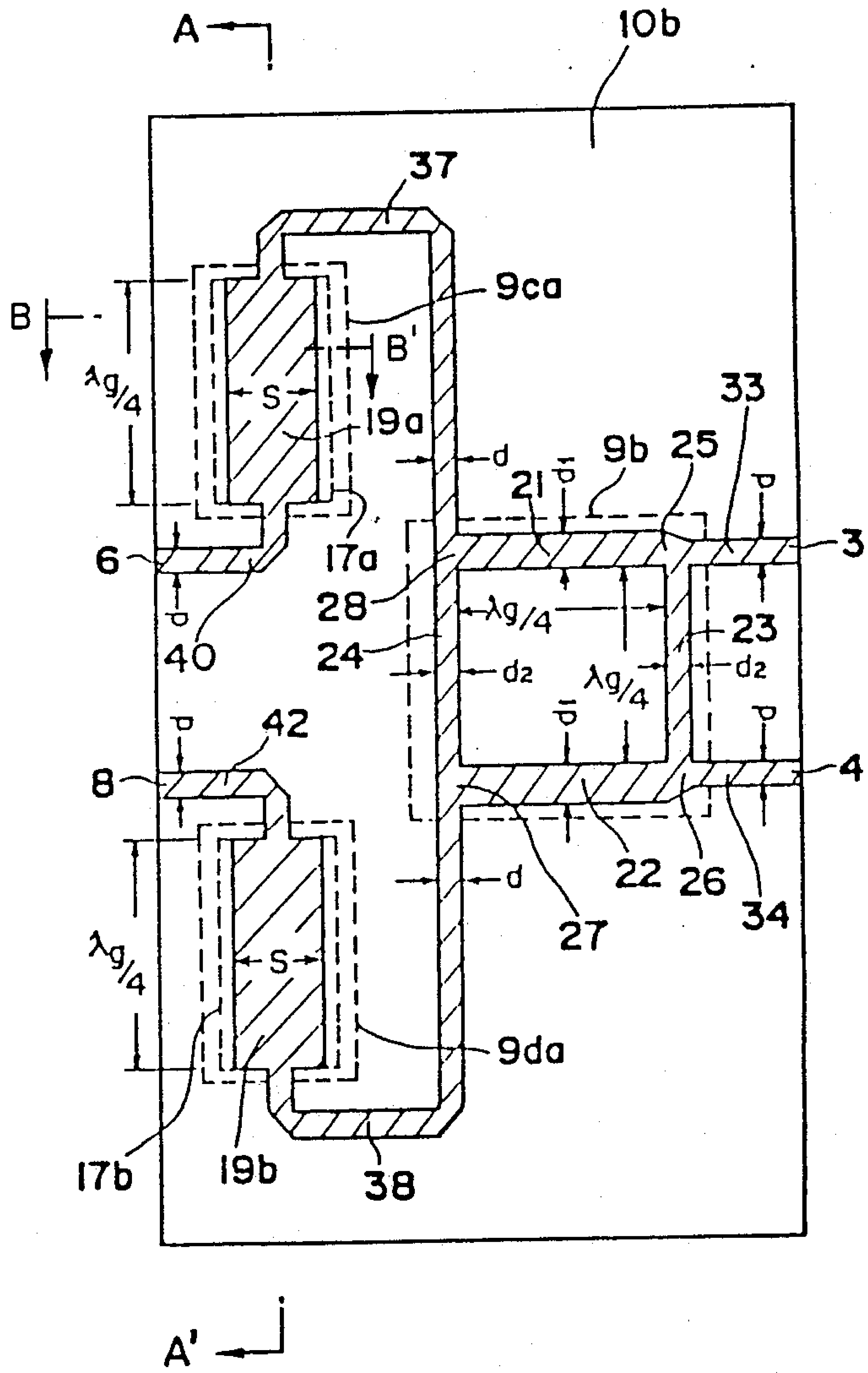

A
A'
B
B'
10b
37
9ca
19a
S
$\lambda g/4$
d
d1
9b
25
33
21
3
6
17a
28
23
d2
40
24
42
8
4
22
26
34
27
9da
17b
19b
38

Fig. 1(C)

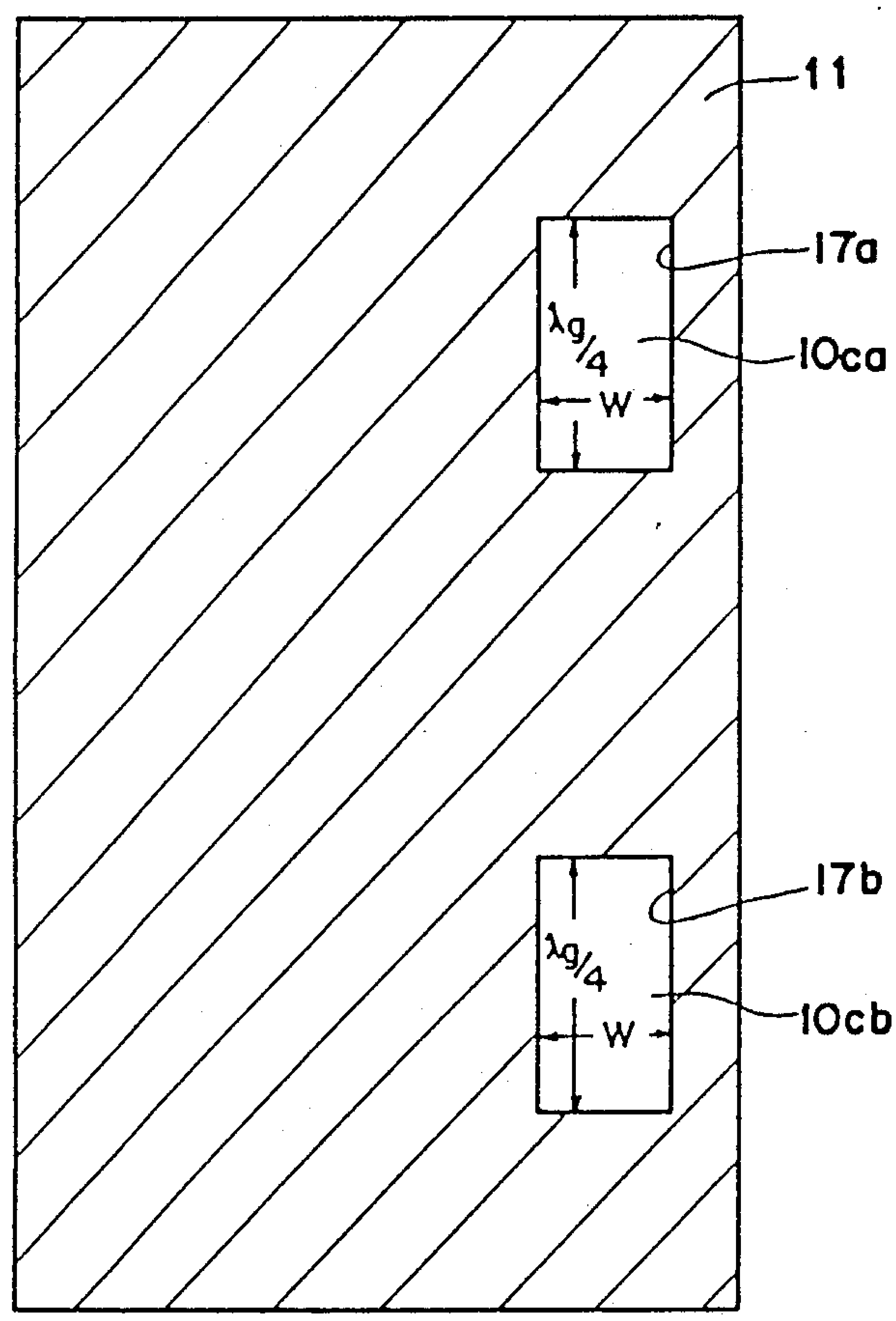
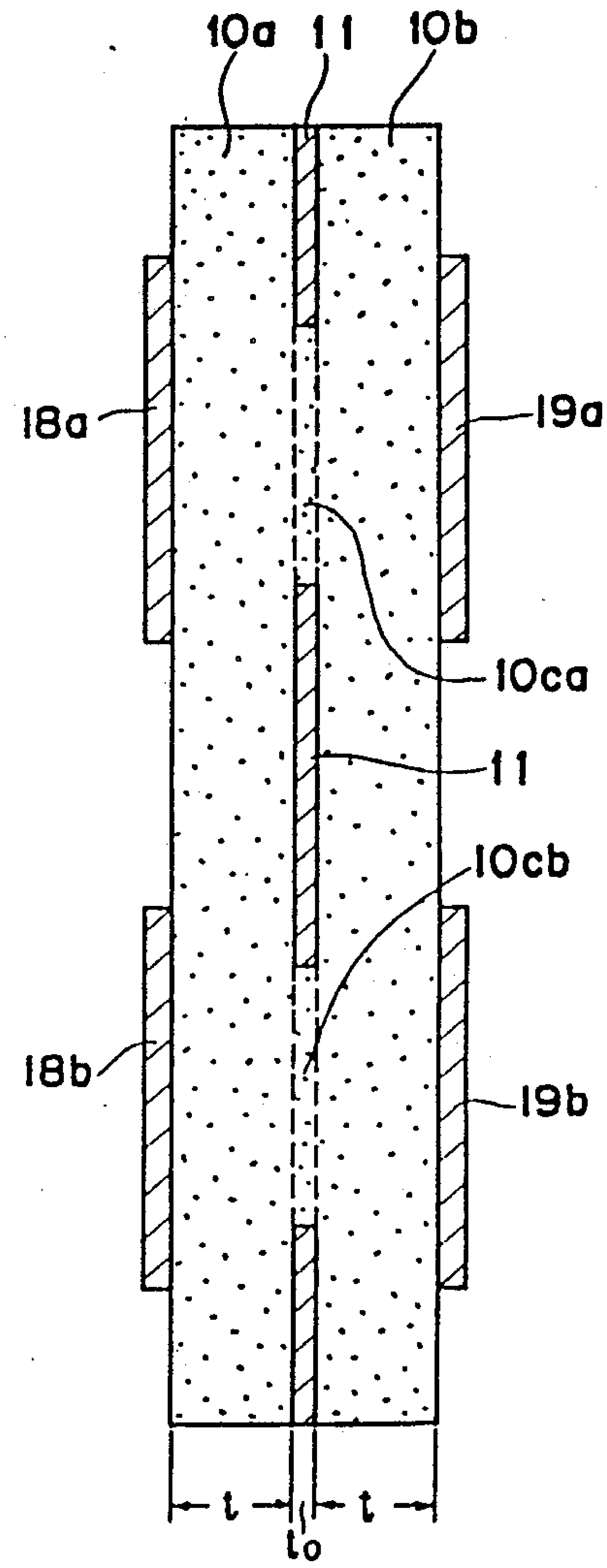

11
17a
λg/4
10ca
W
17b
λg/4
10cb
W

Fig. 1(D)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10b
18a
19a
10ca
11
10cb
18b
19b
t
t
t0

Fig. 2 (A)

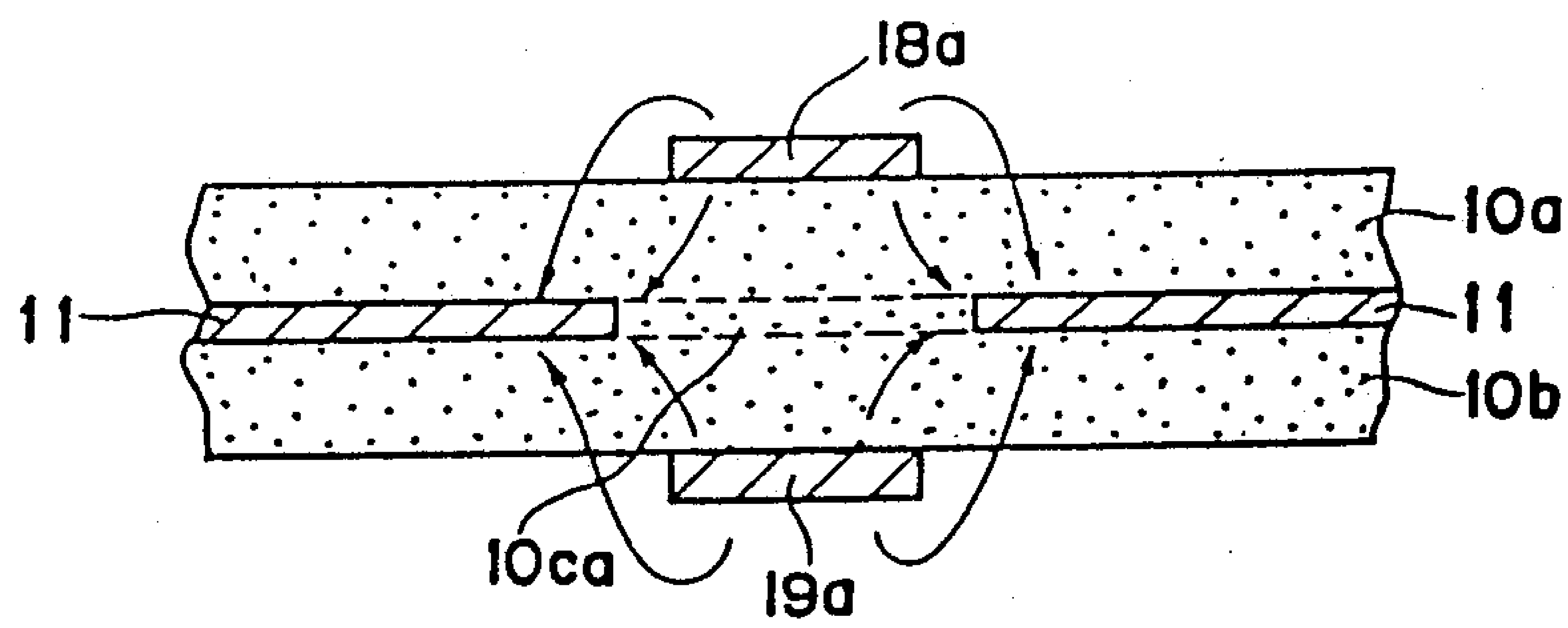


Fig. 2 (B)

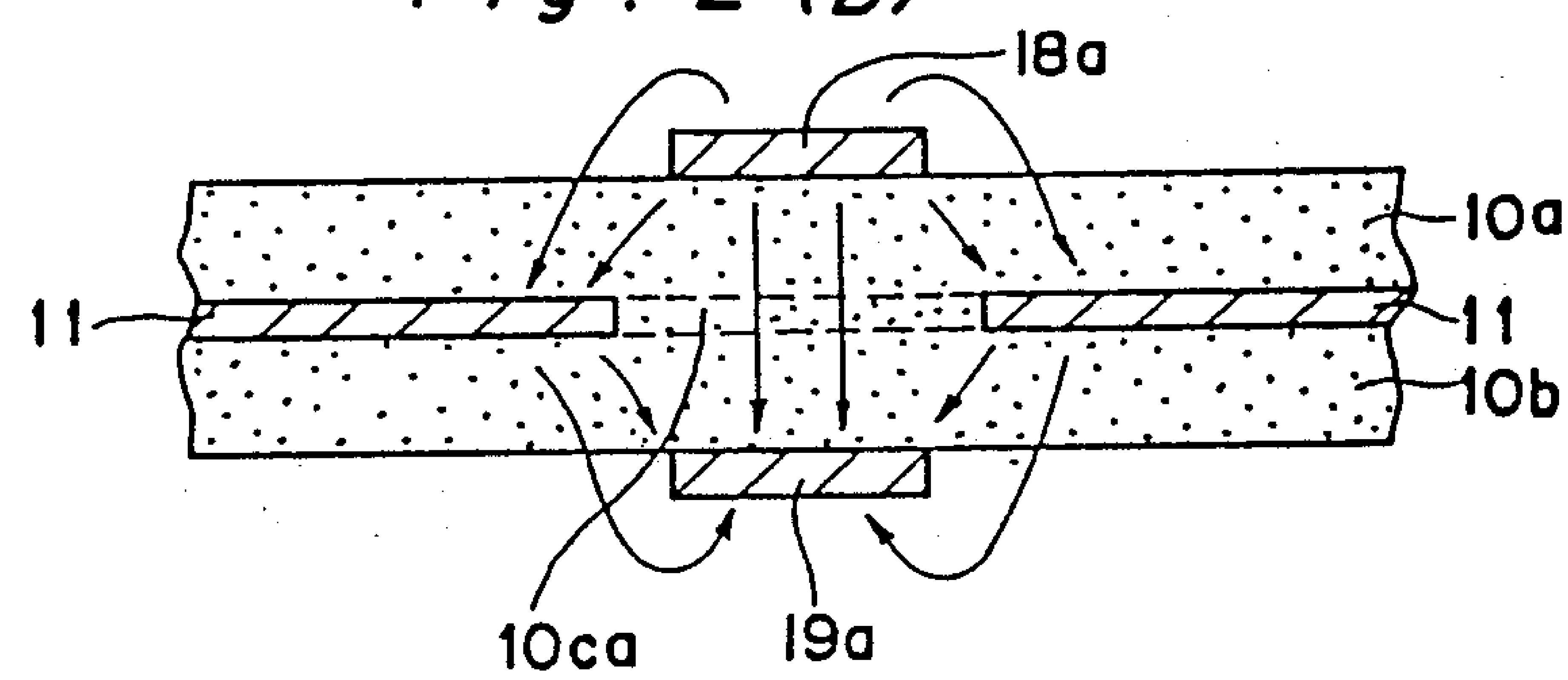
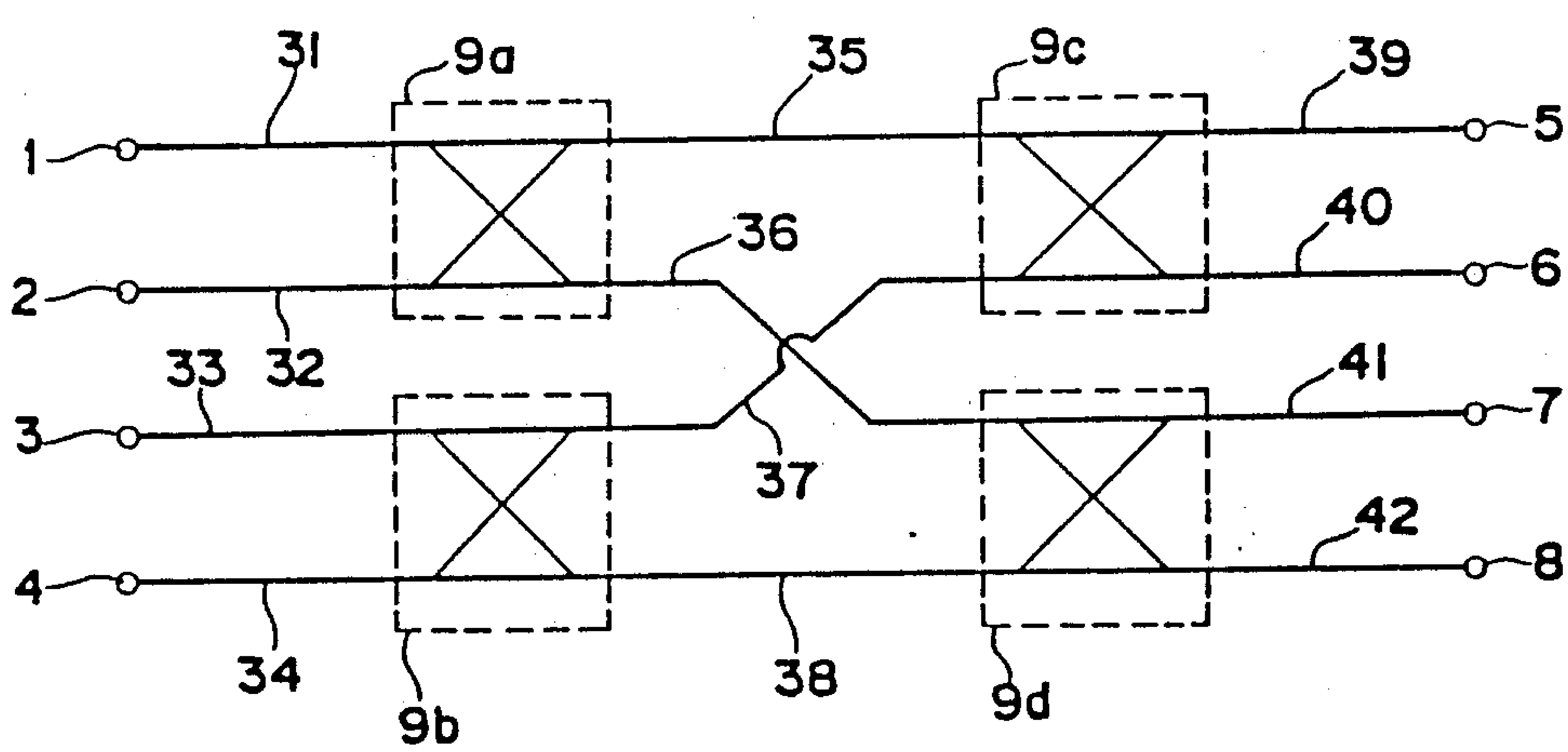
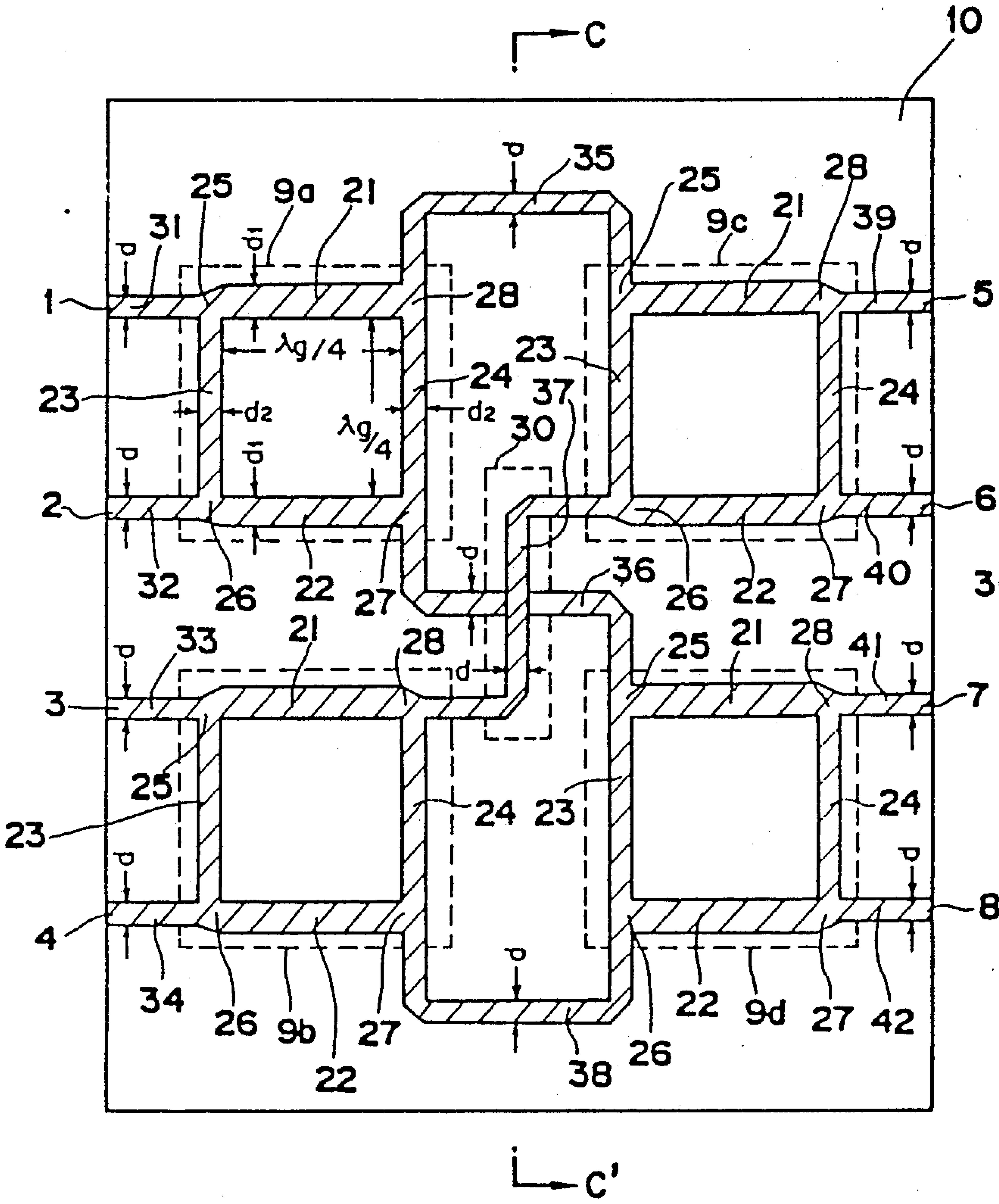


Fig. 3

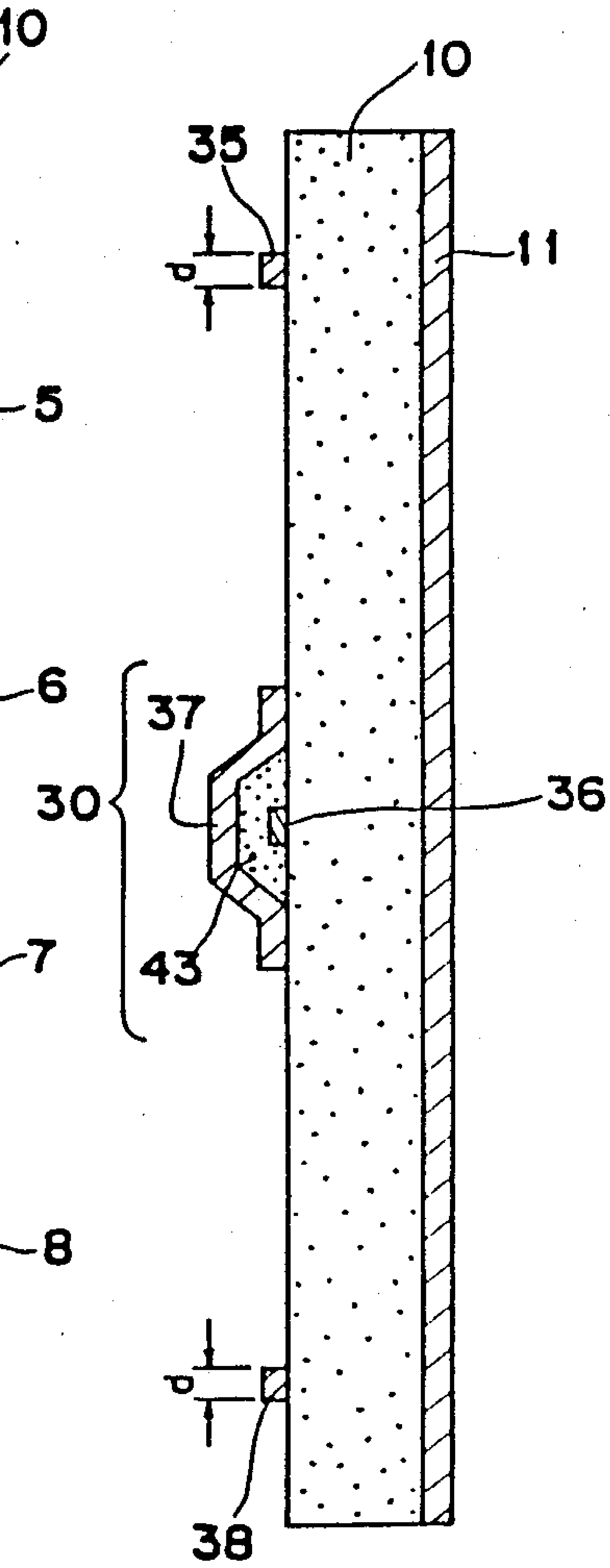


F i g . 4 (A)



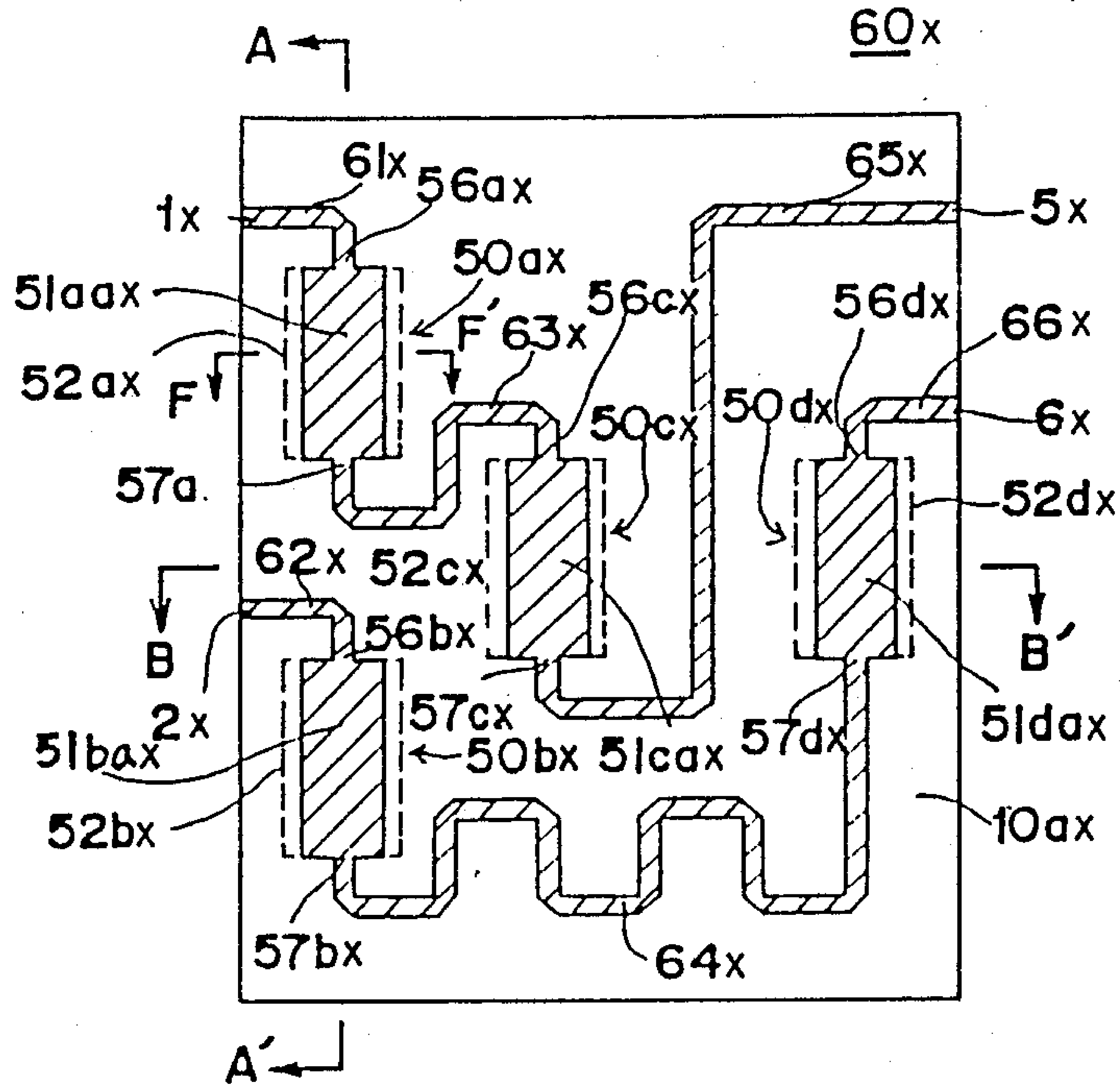
CONVENTIONAL ART

F i g . 4 (B)



CONVENTIONAL ART

Fig. 5(A)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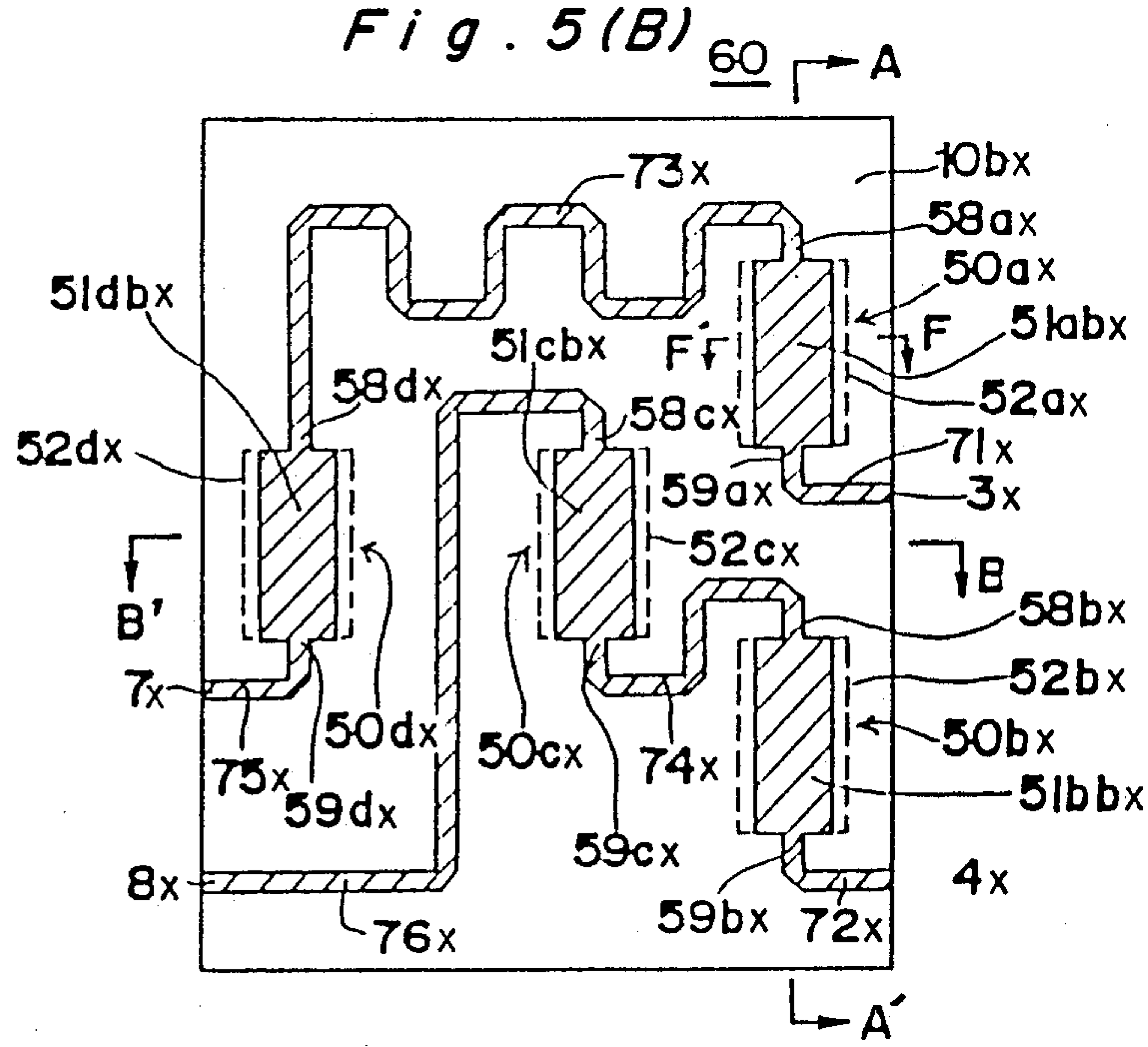
A
A'
B
B'
F
F'
1x
2x
5x
6x
10ax
50ax
50bx
50cx
50dx
51aax
51bax
51cax
51dax
52ax
52bx
52cx
52dx
56ax
56bx
56cx
56dx
57a
57bx
57cx
57dx
61x
62x
63x
64x
65x
66x

Fig. 5(B)


60
A
A'
B
B'
F
F'
3x
4x
7x
8x
10bx
50ax
50bx
50cx
50dx
51abx
51bbx
51cbx
51dbx
52ax
52bx
52cx
52dx
58ax
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59ax
59bx
59cx
59dx
71x
72x
73x
74x
75x
76x

Fig. 5(C)

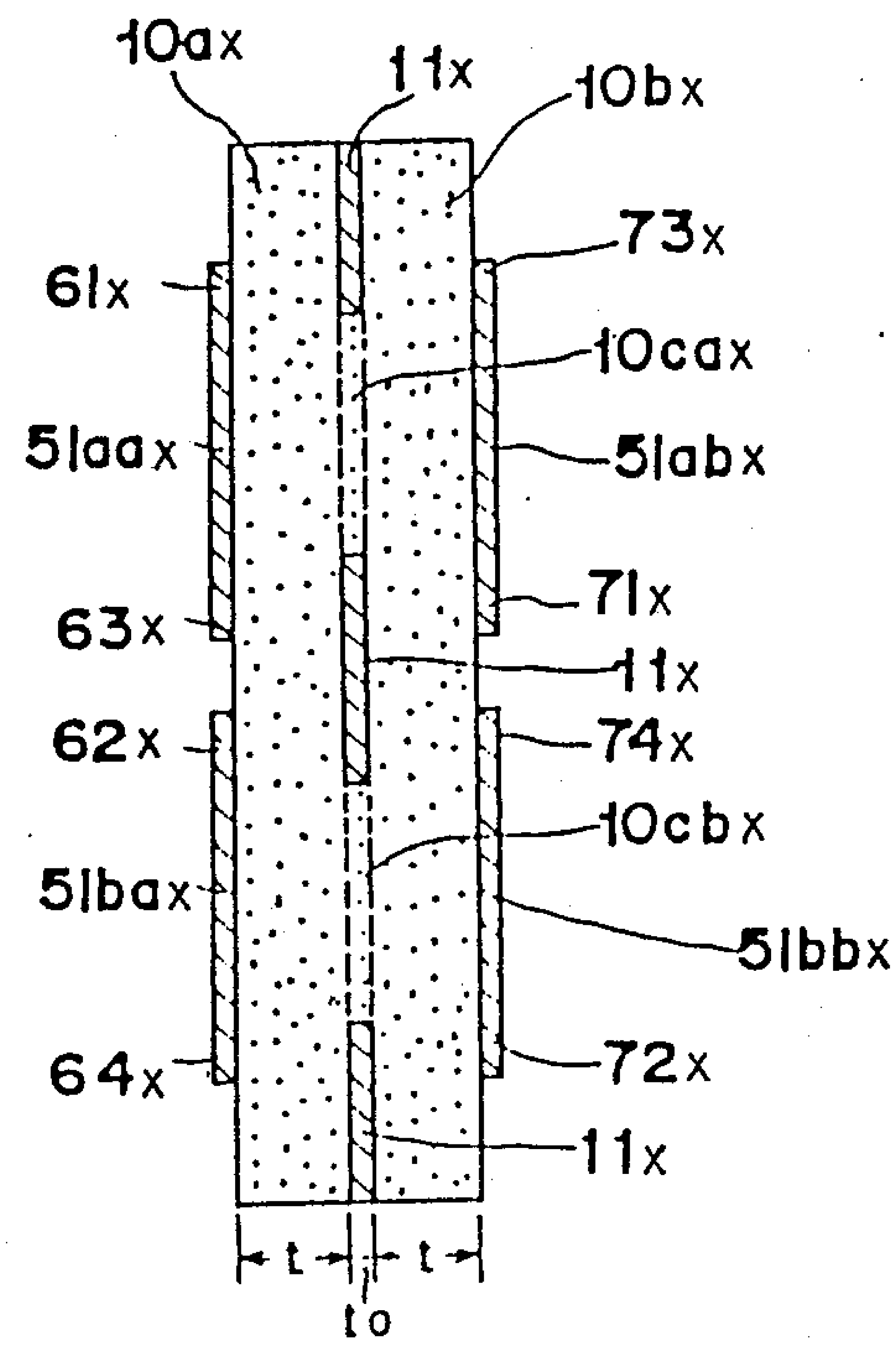

10ax
11x
10bx
73x
61x
10cax
51aax
51abx
71x
63x
11x
62x
74x
10cbx
51bax
51bbx
64x
72x
11x
t
t
to

Fig. 5(D)

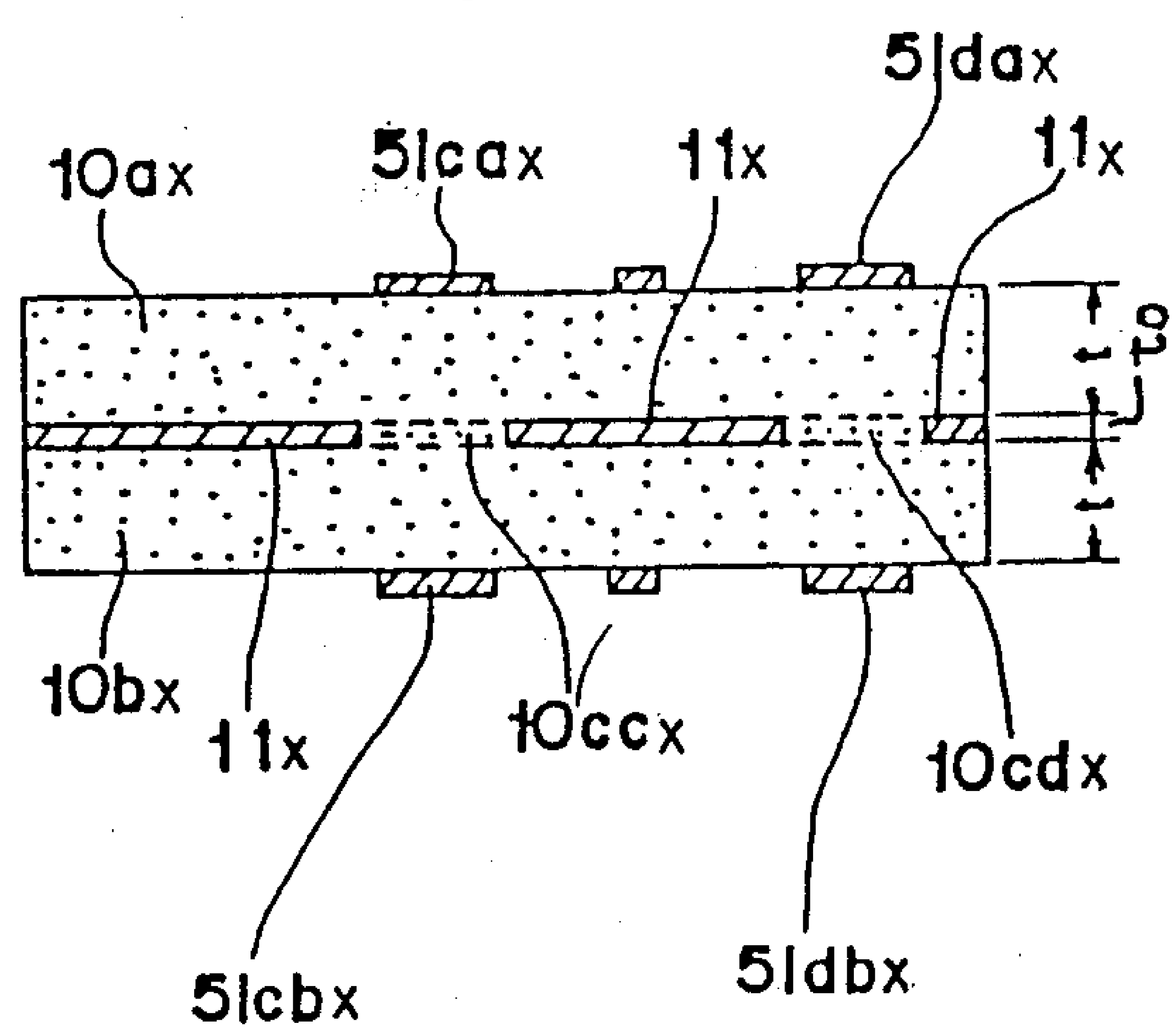

51dax
10ax
51cax
11x
11x
t
to
t
10bx
11x
10ccx
10cdx
51cbx
51dbx

Fig. 6 (A)

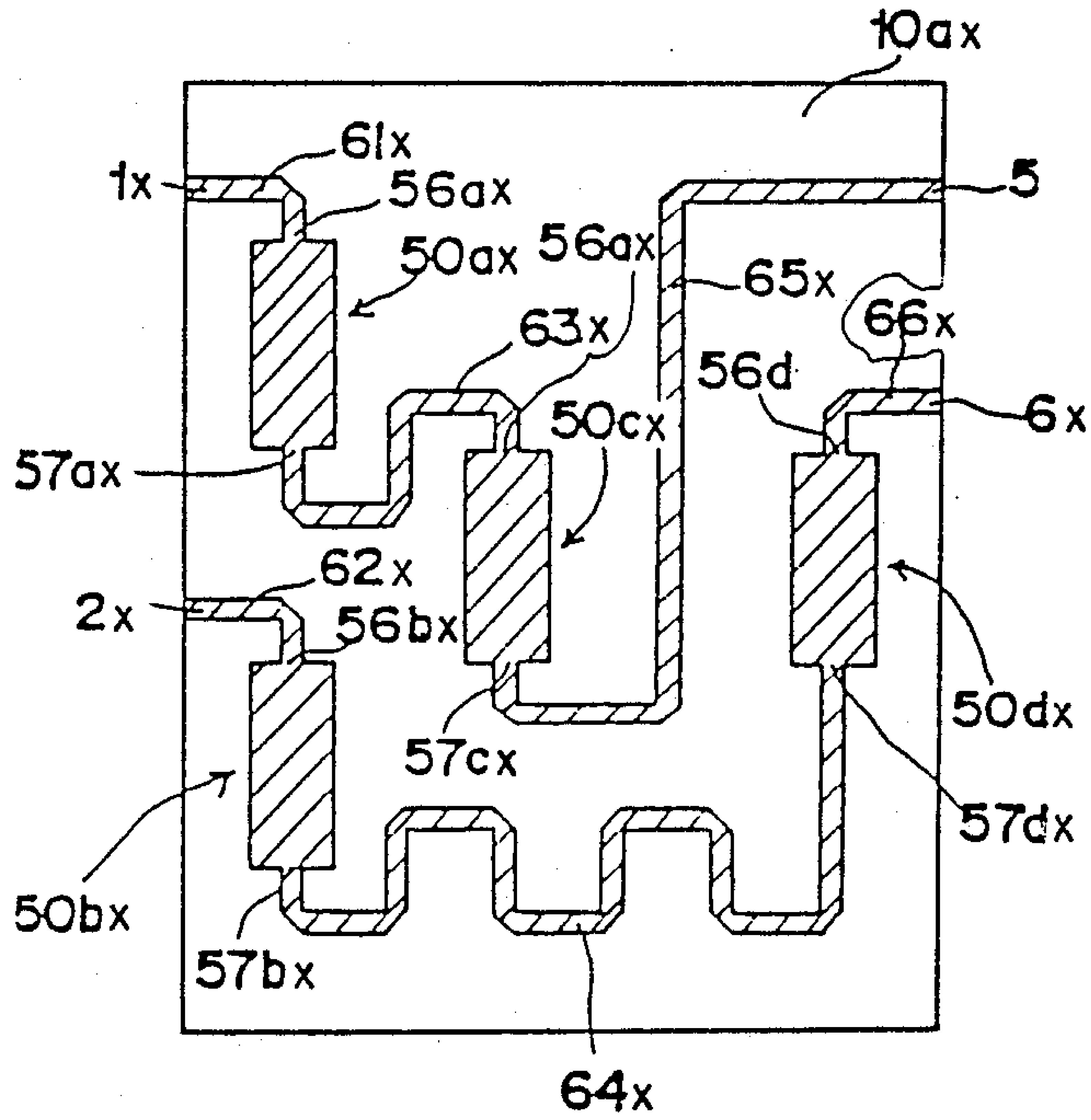

10ax
61x
1x
56ax
5
50ax
56ax
65x
63x
66x
56d
6x
57ax
50cx
62x
2x
56bx
50dx
57cx
57dx
50bx
57bx
64x

Fig. 6 (B)

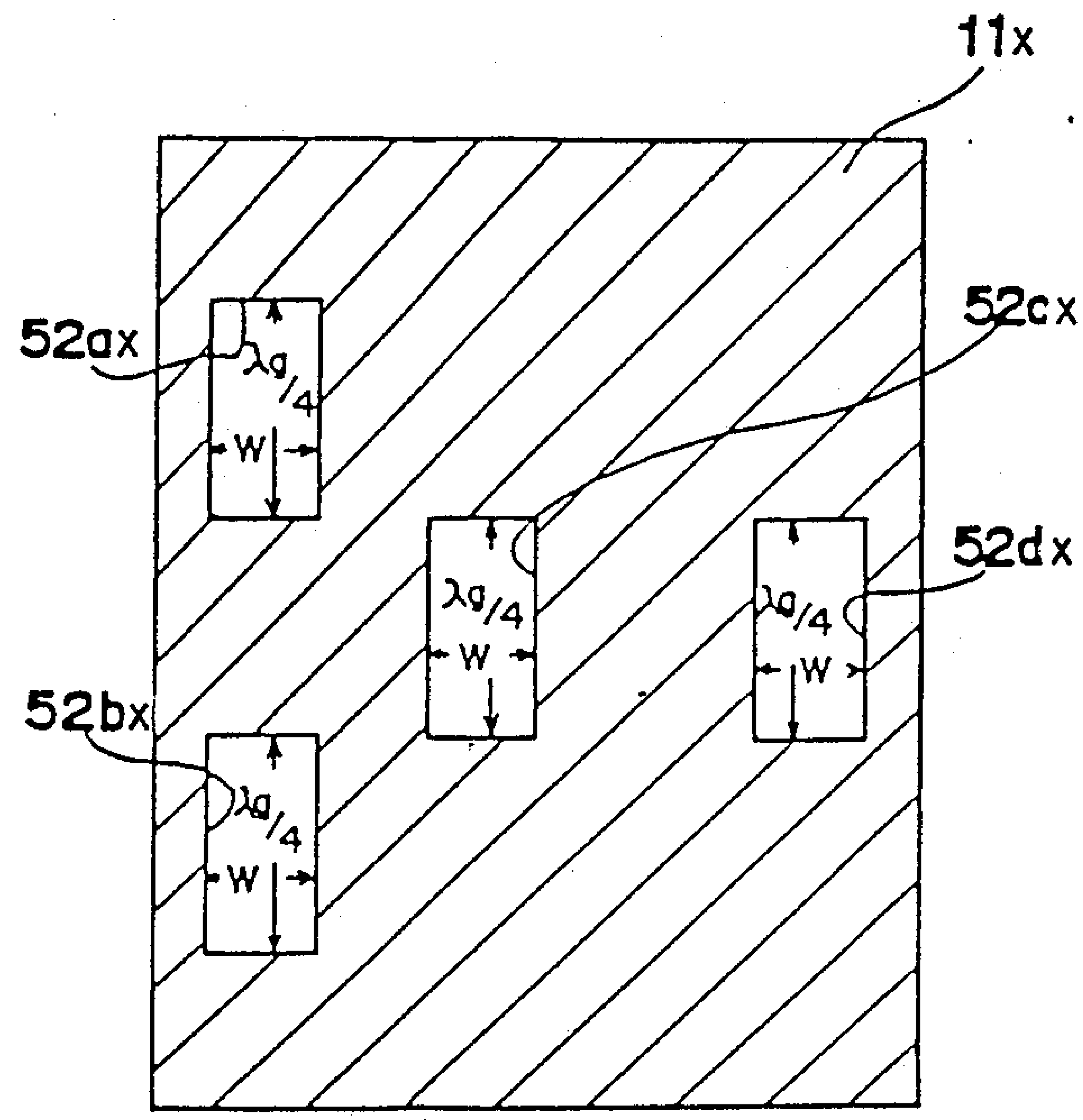
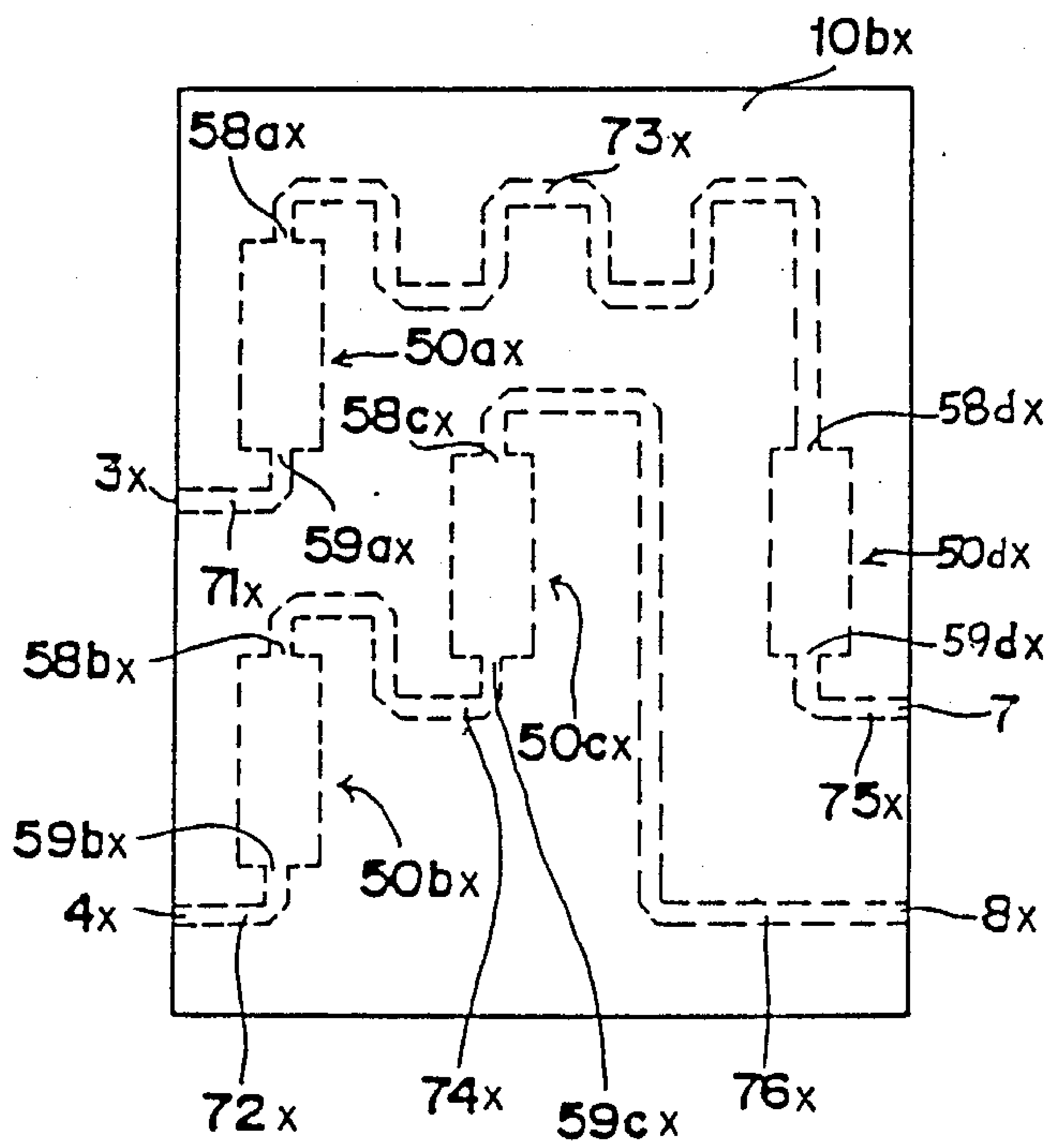


Fig. 6 (C)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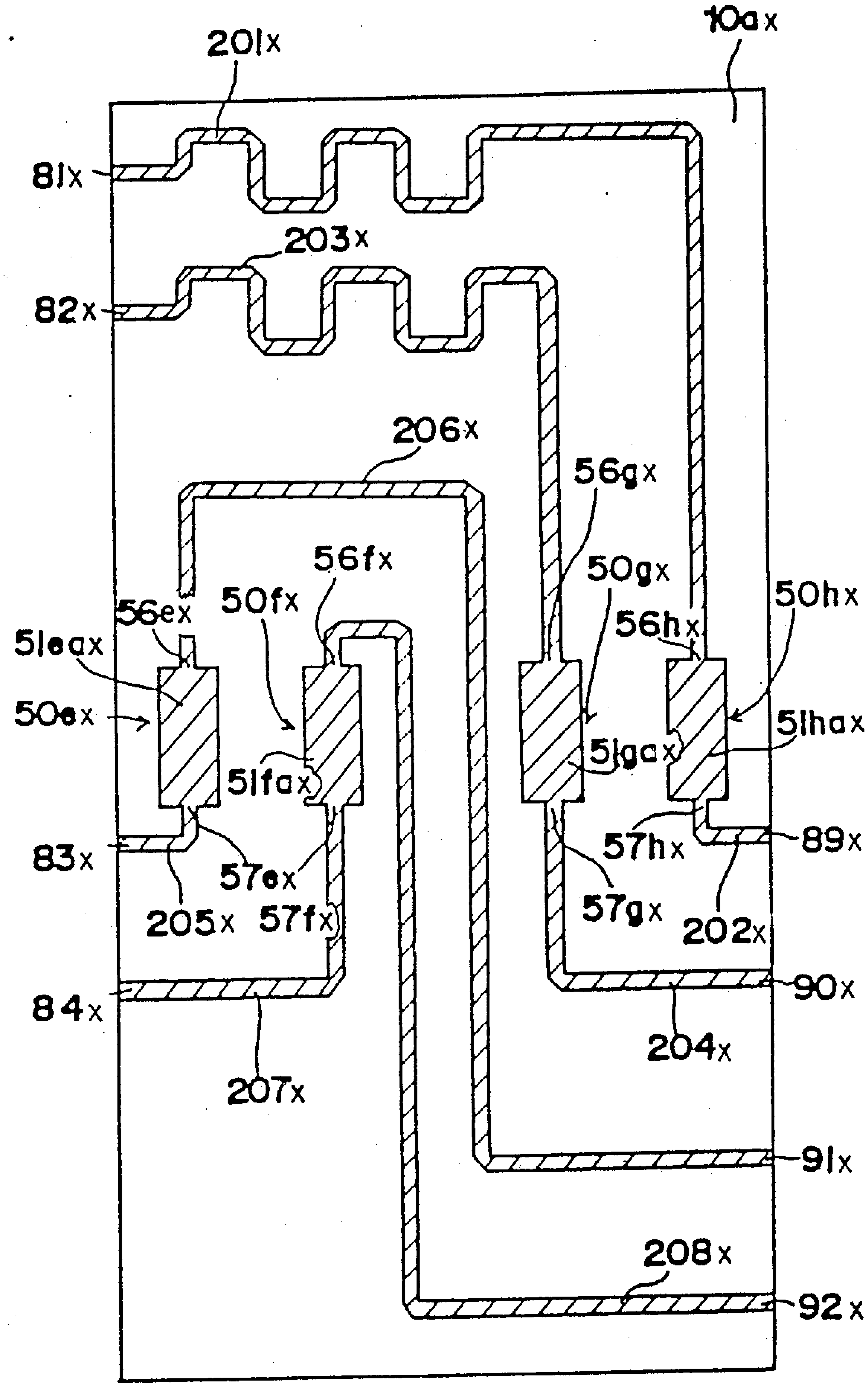
58ax
73x
50ax
58cx
58dx
3x
59ax
71x
50dx
58bx
59dx
7
50cx
75x
59bx
50bx
4x
8x
72x
74x
59cx
76x

F i g . 7 (A)


10ax
201x
81x
203x
82x
206x
56gx
56fx
50gx
50hx
56ex
50fx
56hx
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50ex
51hax
51gax
51fax
83x
57hx
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202x
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84x
204x
207x
91x
208x
92x

Fig. 7 (B)

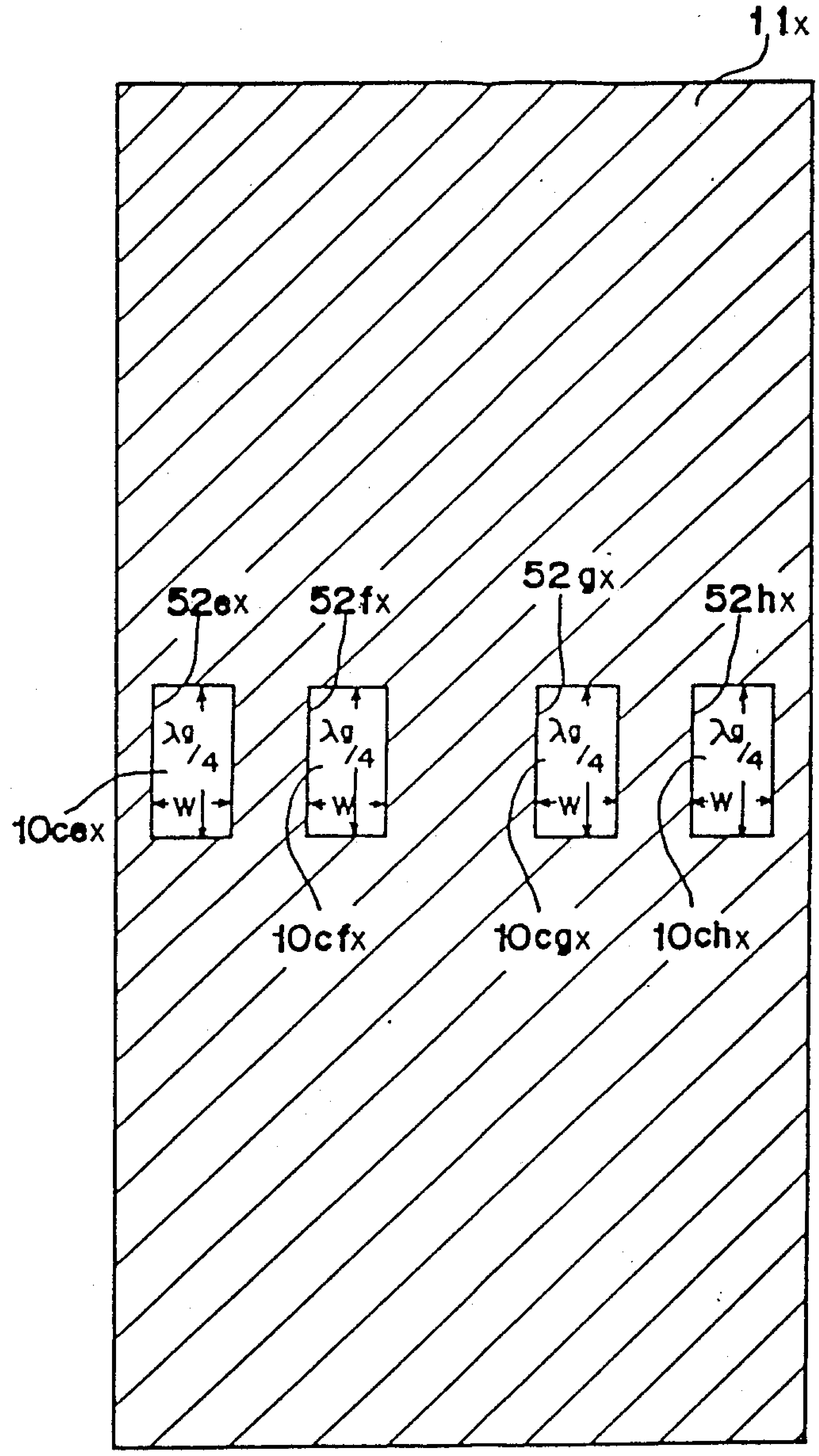


Fig. 7(C)

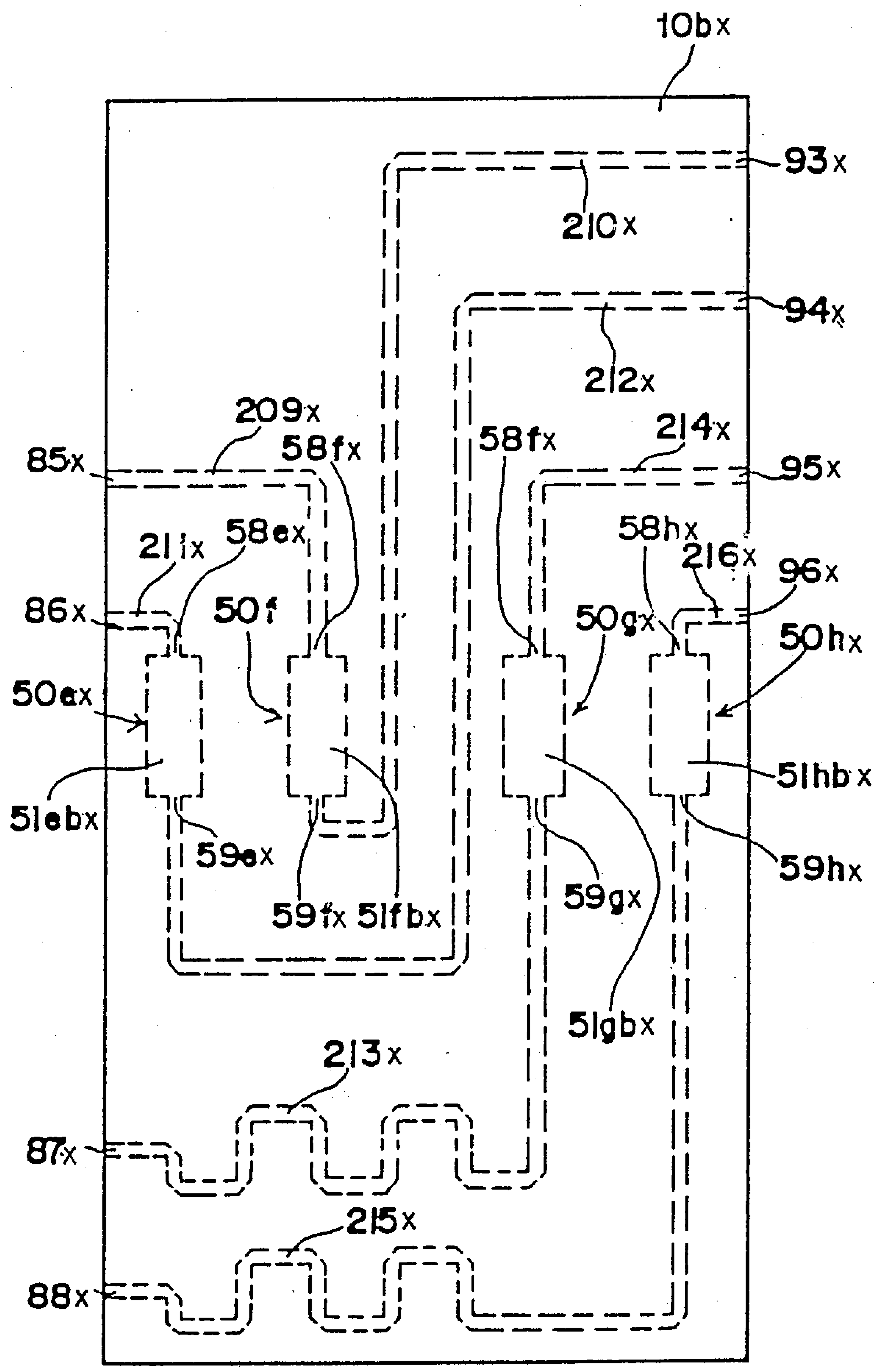
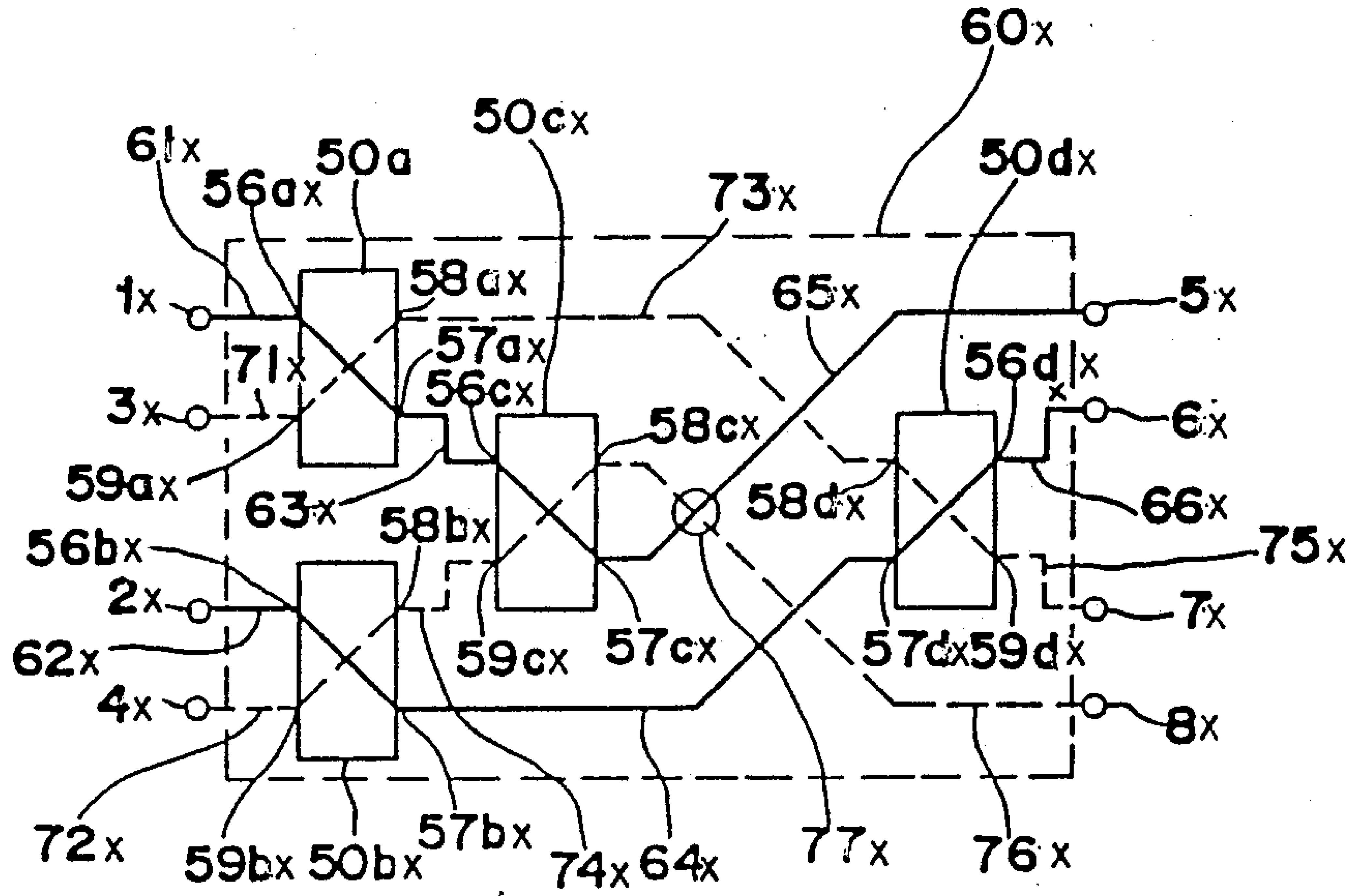

10bx
93x
210x
94x
212x
209x
58fx
58fx
214x
85x
95x
211x
58ex
58hx
216x
96x
86x
50f
50gx
50hx
50ex
51ebx
51hbx
59ex
59fx
51fbx
59gx
59hx
51gbx
213x
87x
215x
88x

Fig. 8 (A)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50cx
61x
56ax
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73x
50dx
1x
58ax
5x
65x
57ax
71x
56dx
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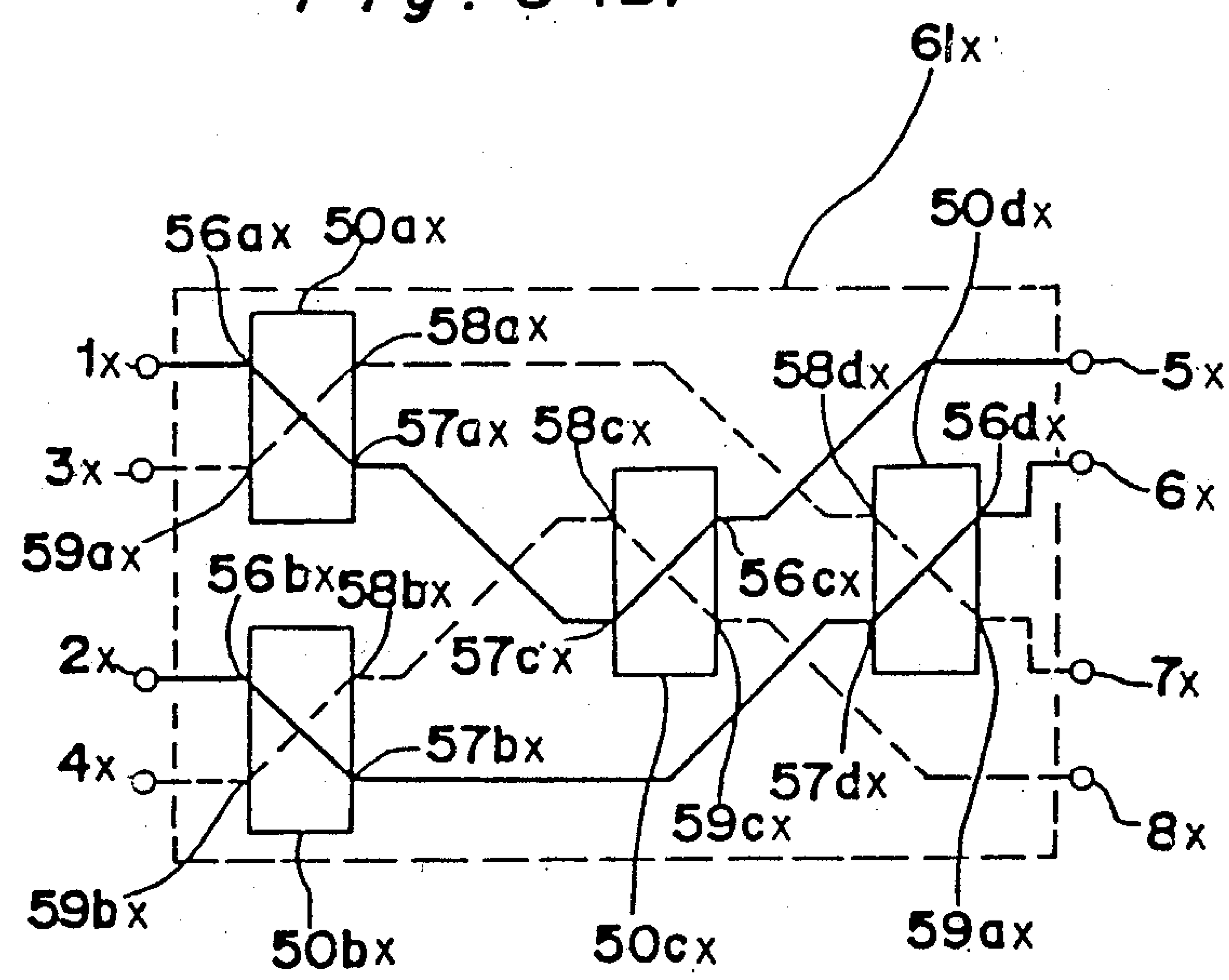
56cx
6x
58cx
59ax
63x
58dx
66x
56bx
58bx
75x
2x
7x
62x
59cx
57cx
57dx
59dx
4x
8x
72x
59bx
50bx
57bx
74x
64x
77x
76x

Fig. 8 (B)


61x
50dx
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50ax
58ax
1x
58dx
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57ax
58cx
56dx
3x
6x
59ax
56bx
58bx
56cx
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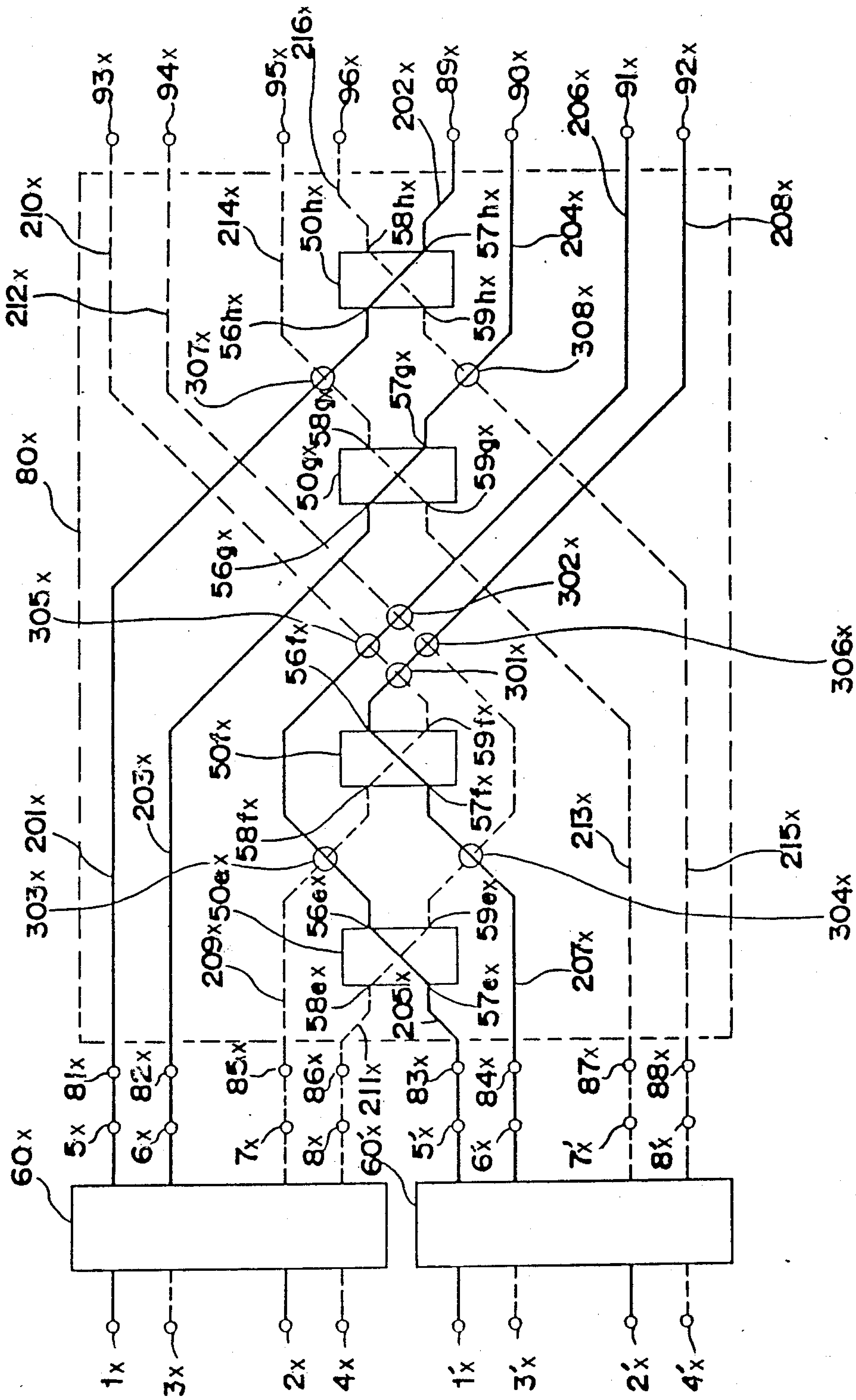
57cx
7x
4x
57bx
57dx
59cx
8x
59bx
50bx
50cx
59ax

Fig. 9


93x
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95x
216x
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89x
90x
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91x
92x
210x
214x
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212x
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308x
57gx
58gx
80x
50gx
59gx
56gx
302x
305x
306x
56fx
301x
59fx
50fx
57fx
203x
201x
58fx
213x
215x
303x
50ex
304x
209x
56ex
59ex
207x
58ex
205x
57ex
211x
81x
82x
85x
86x
83x
84x
87x
88x
5x
6x
7x
8x
60'x
5'x
6'x
7'x
8'x
60x
1x
3x
2x
4x
1'x
3'x
2'x
4'x

Fig. 10 (A)

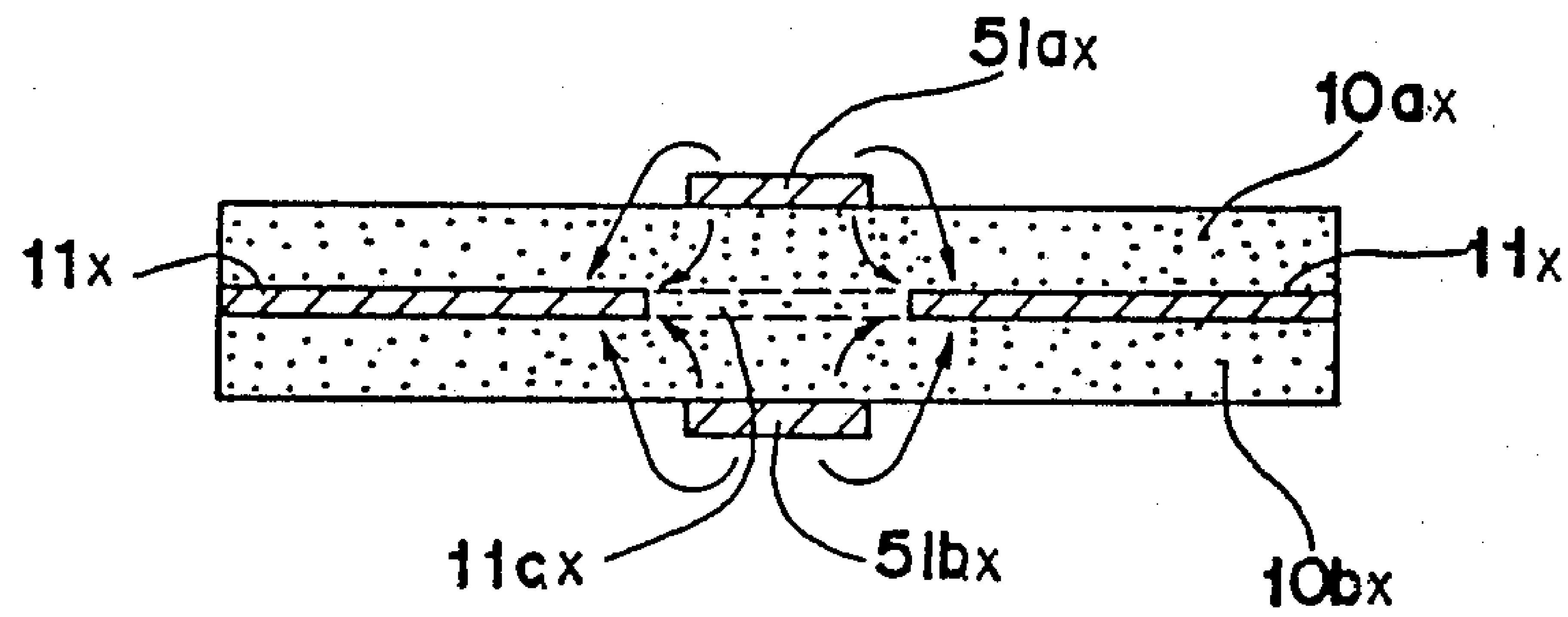


Fig. 10 (B)

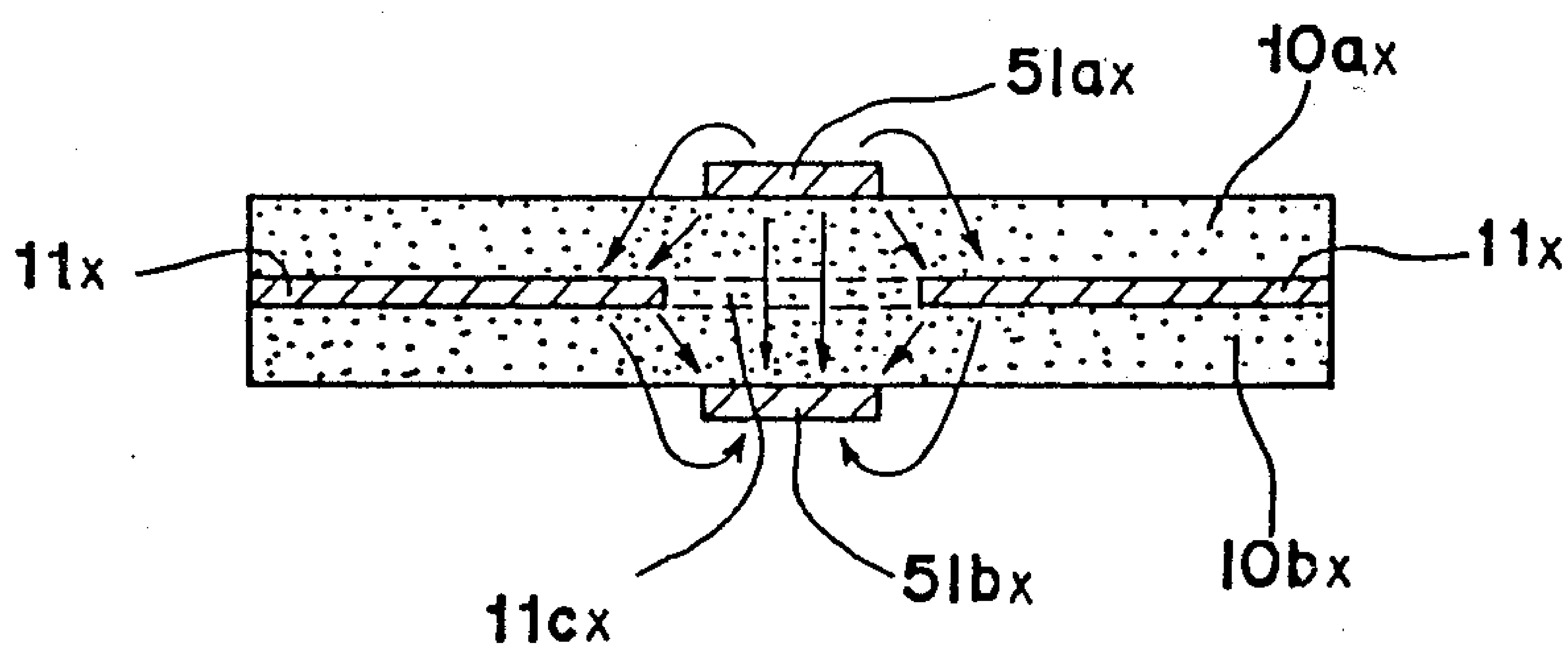


Fig. 11
CONVENTIONAL ART

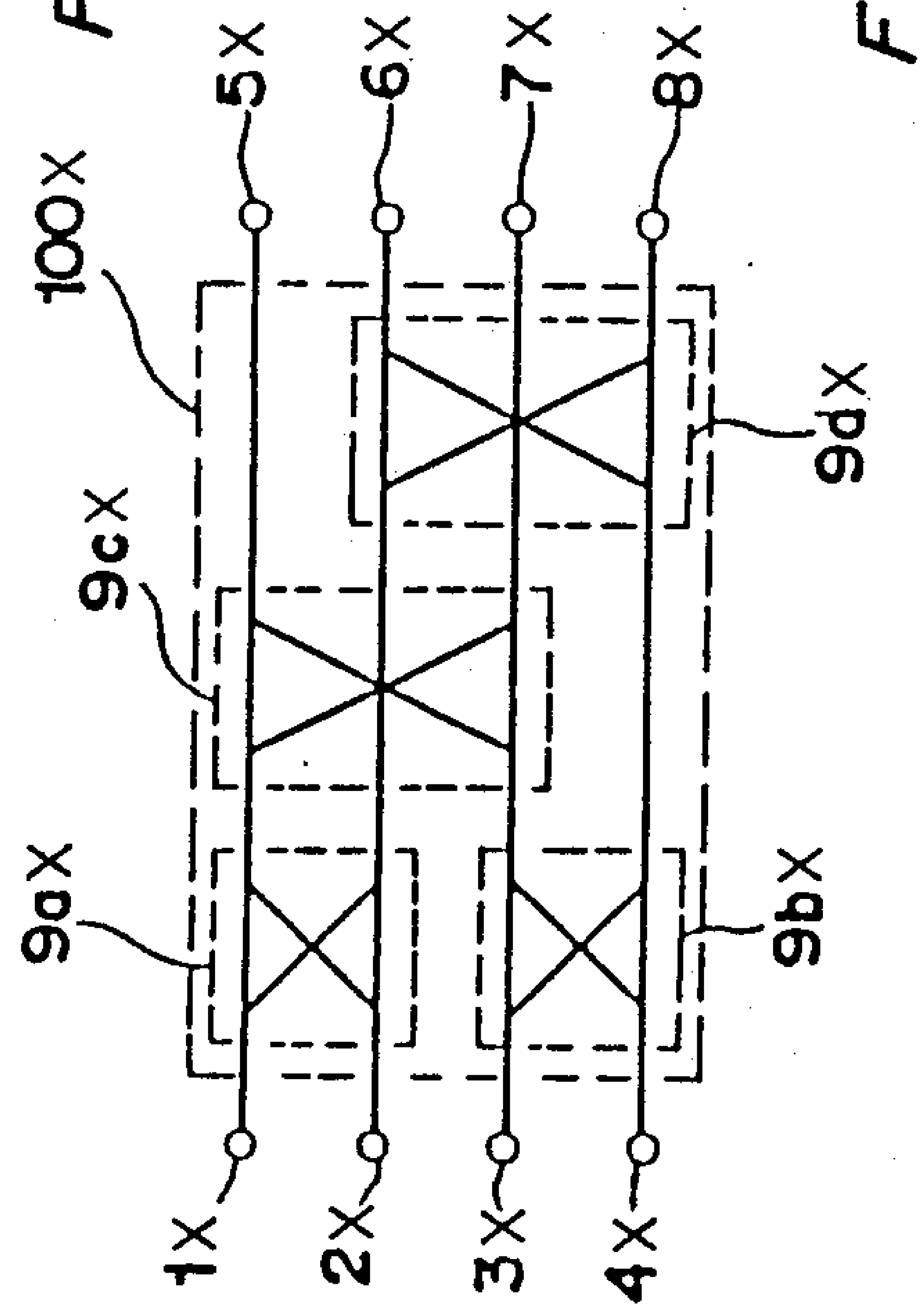
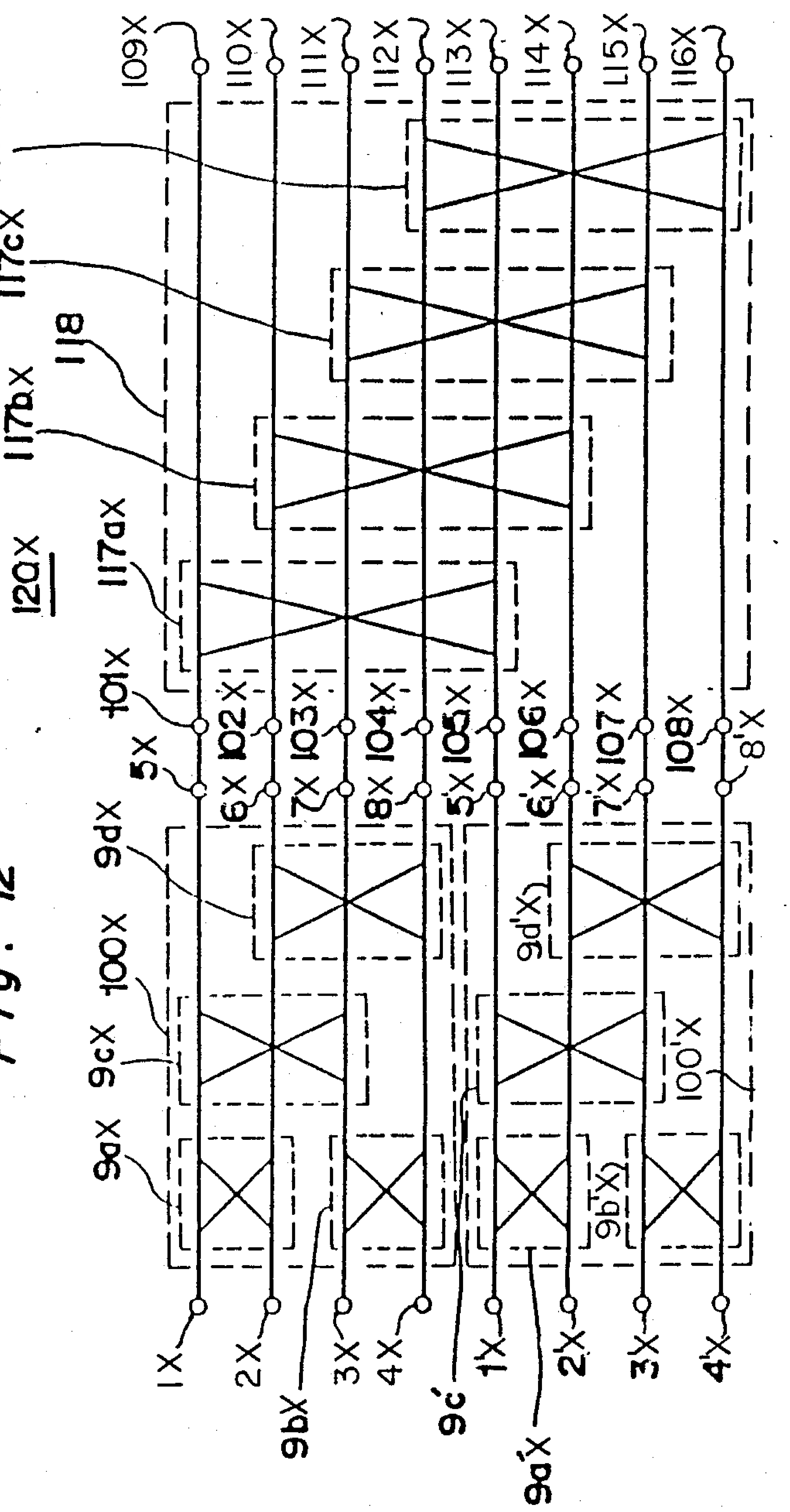


Fig. 12
CONVENTIONAL ART



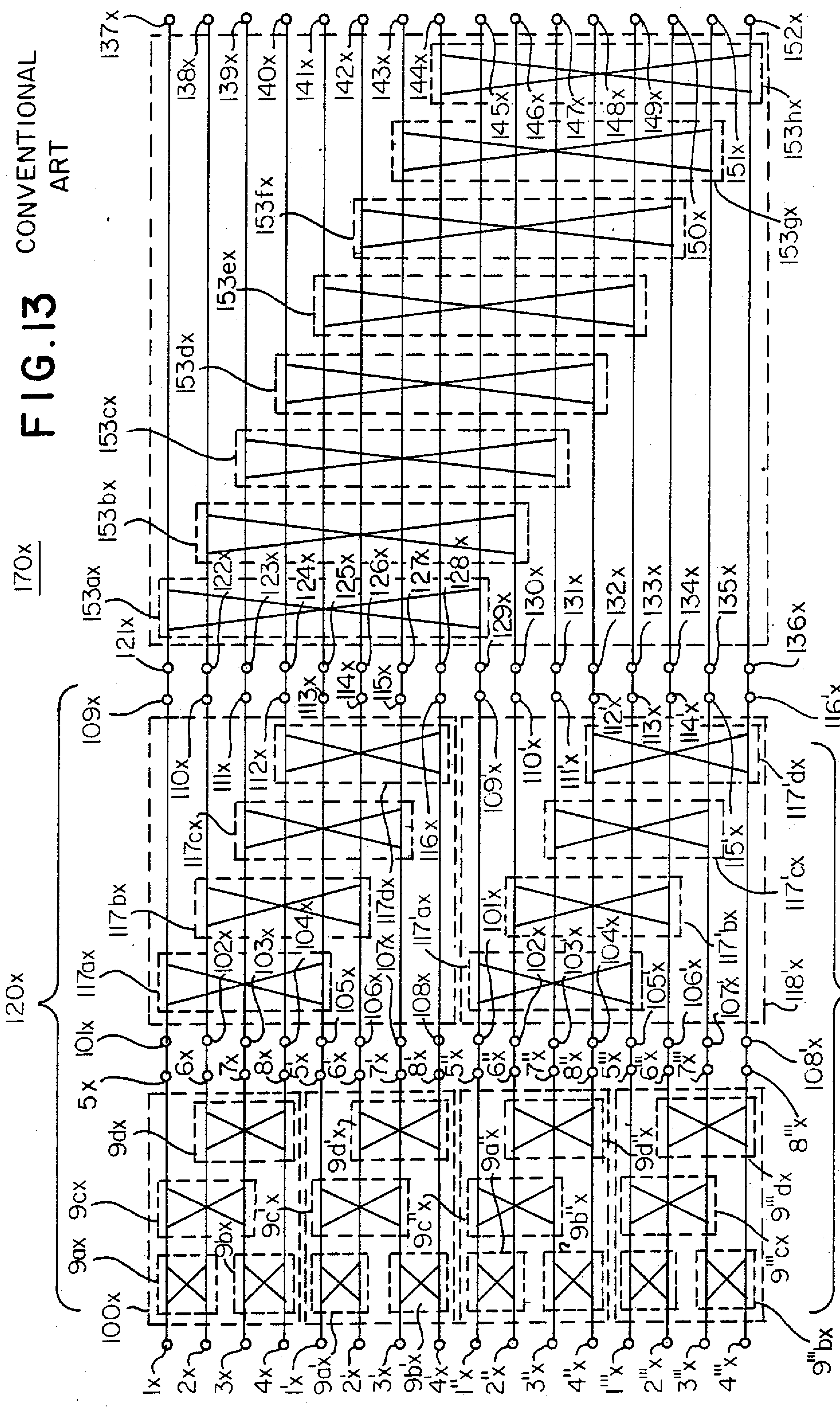
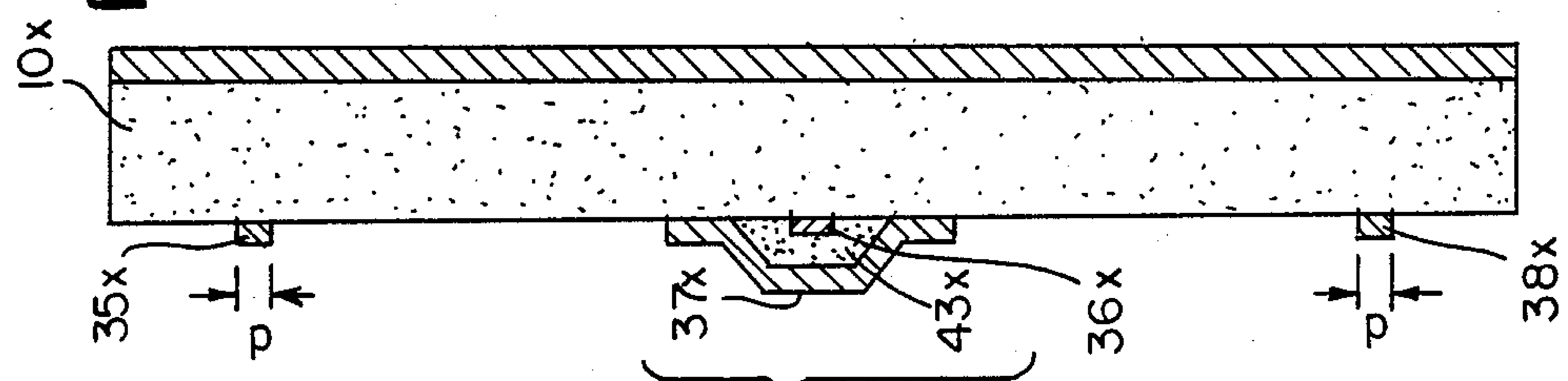


FIG. 13 CONVENTIONAL ART

FIG. 14(B)
CONVENTIONAL ART



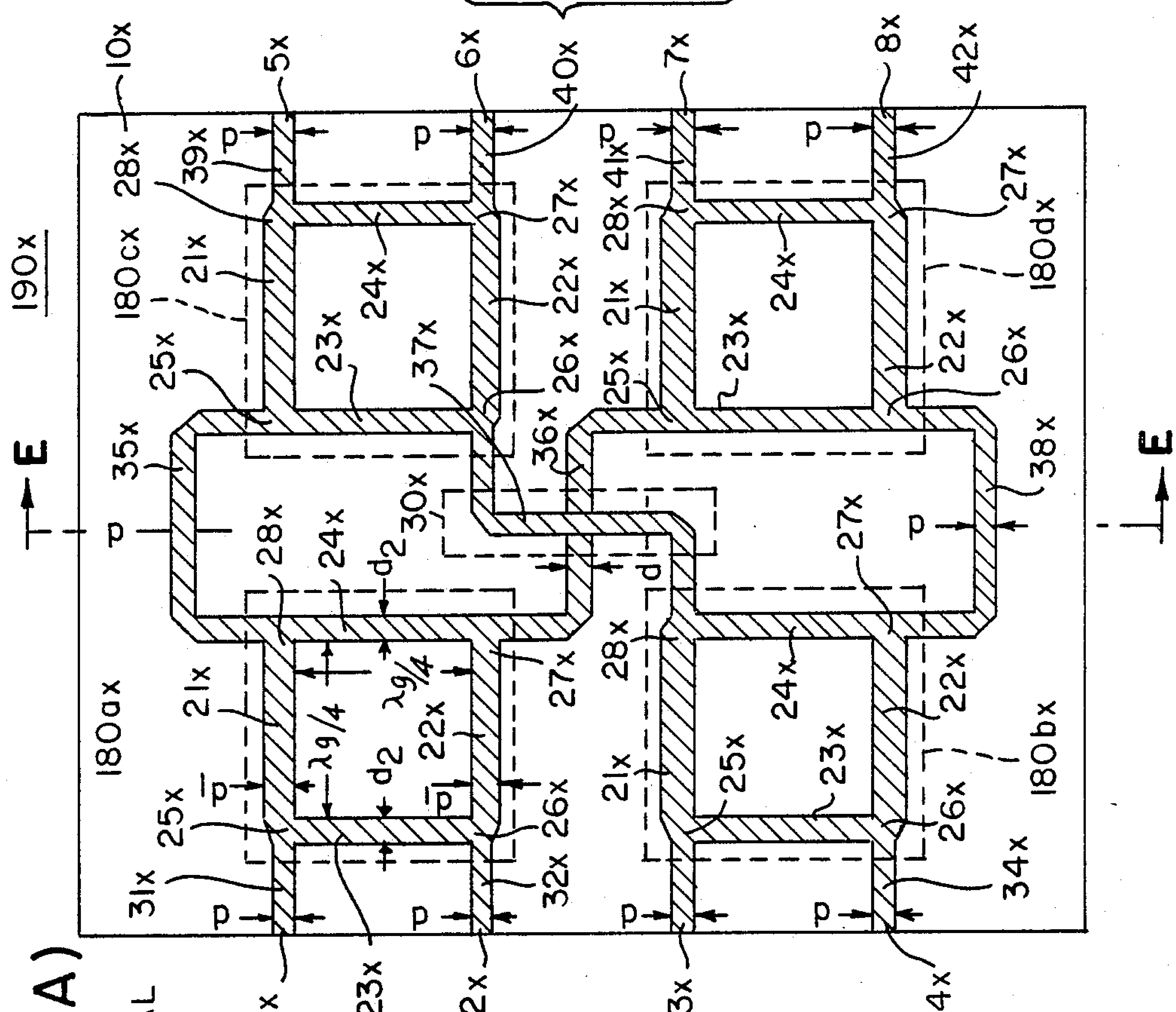


FIG. 14(A)
CONVENTIONAL ART

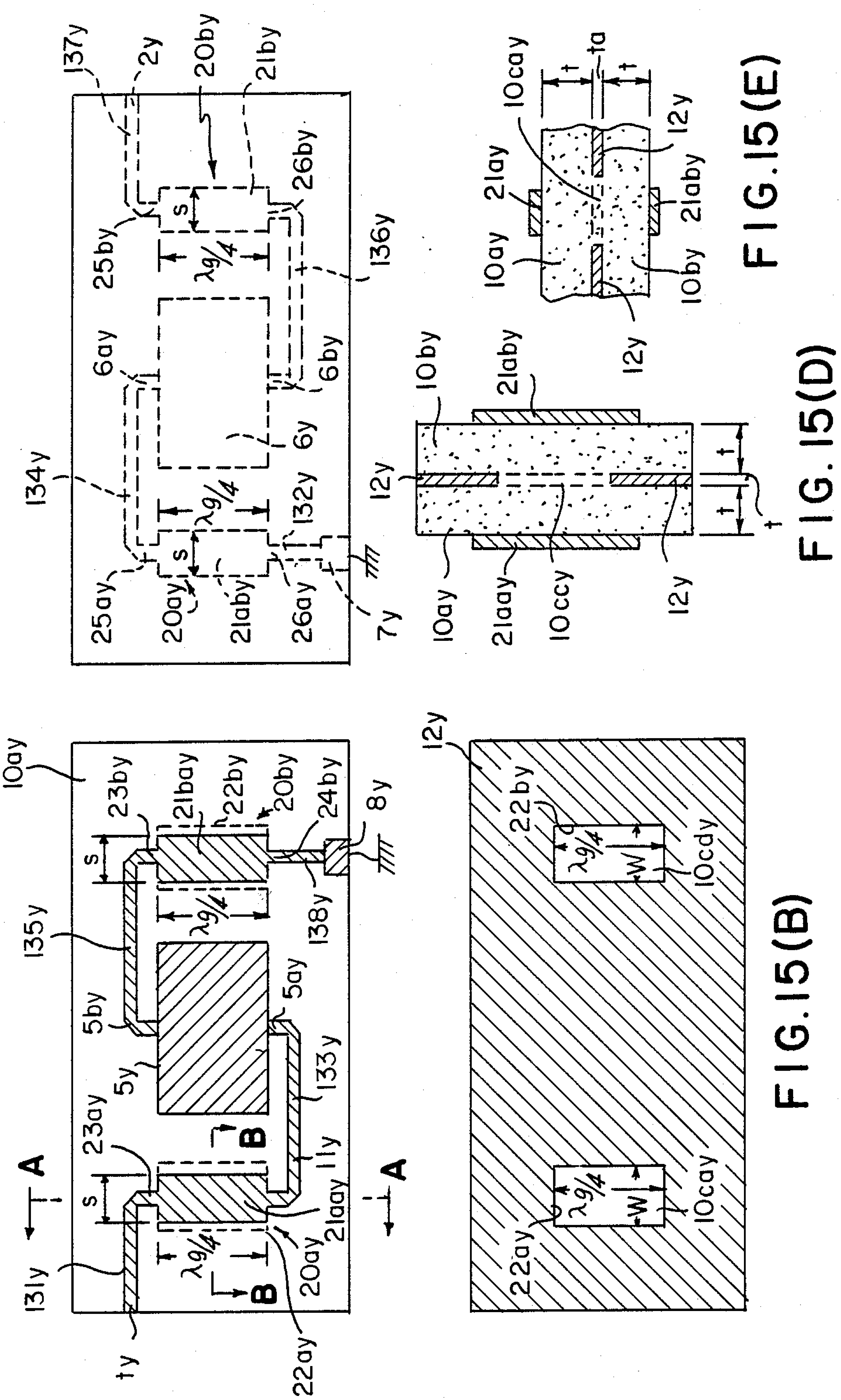


FIG. 15(C)

FIG. 15(A)

FIG. 15(D)

FIG. 15(E)

FIG. 15(B)

Fig. 16(A)

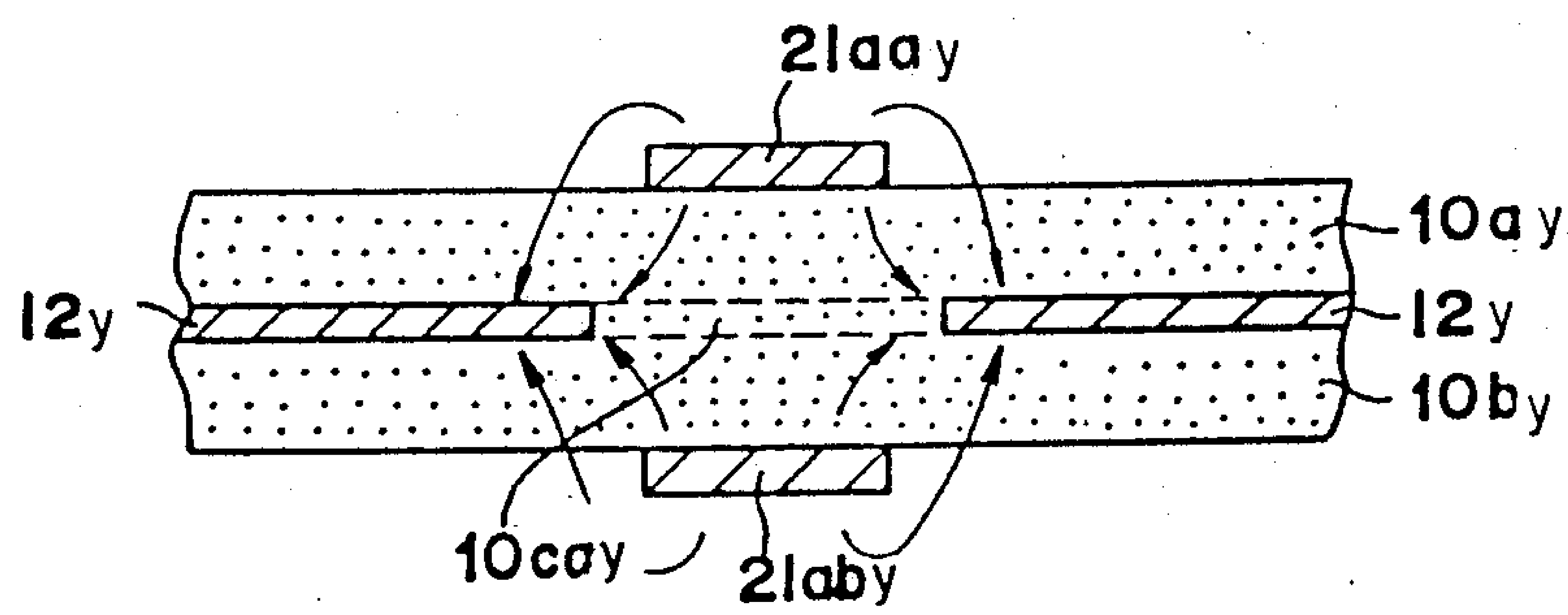


Fig. 16(B)

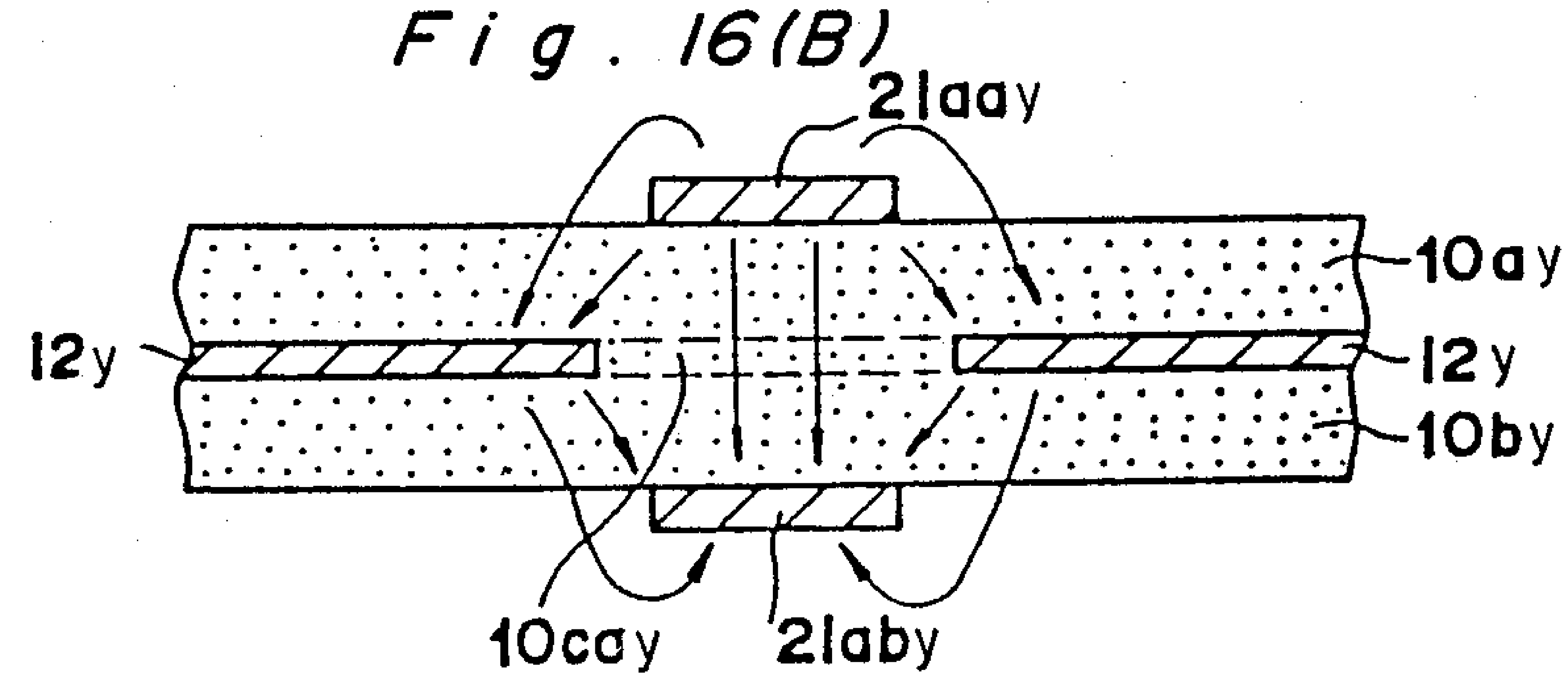


Fig. 17

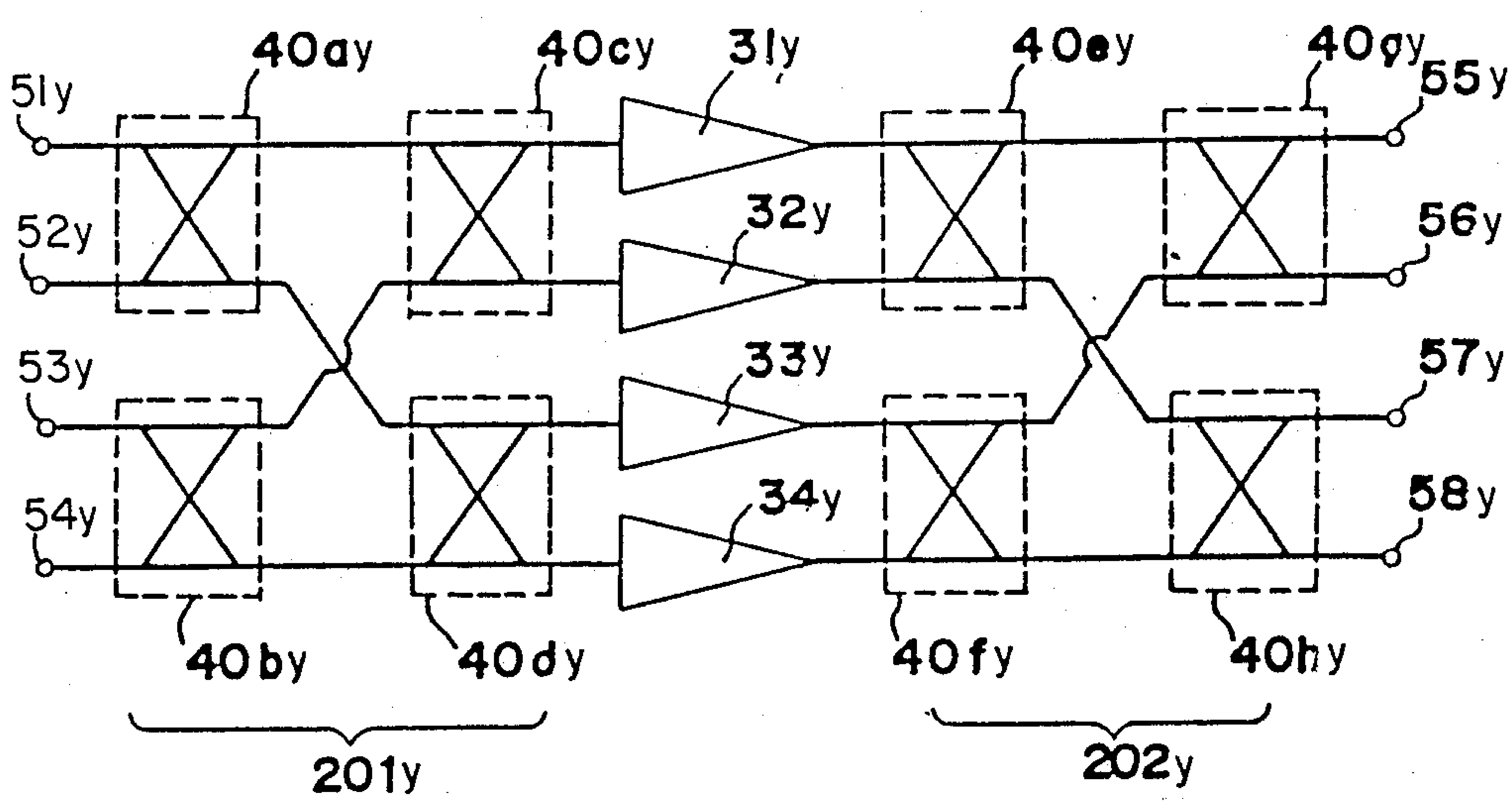
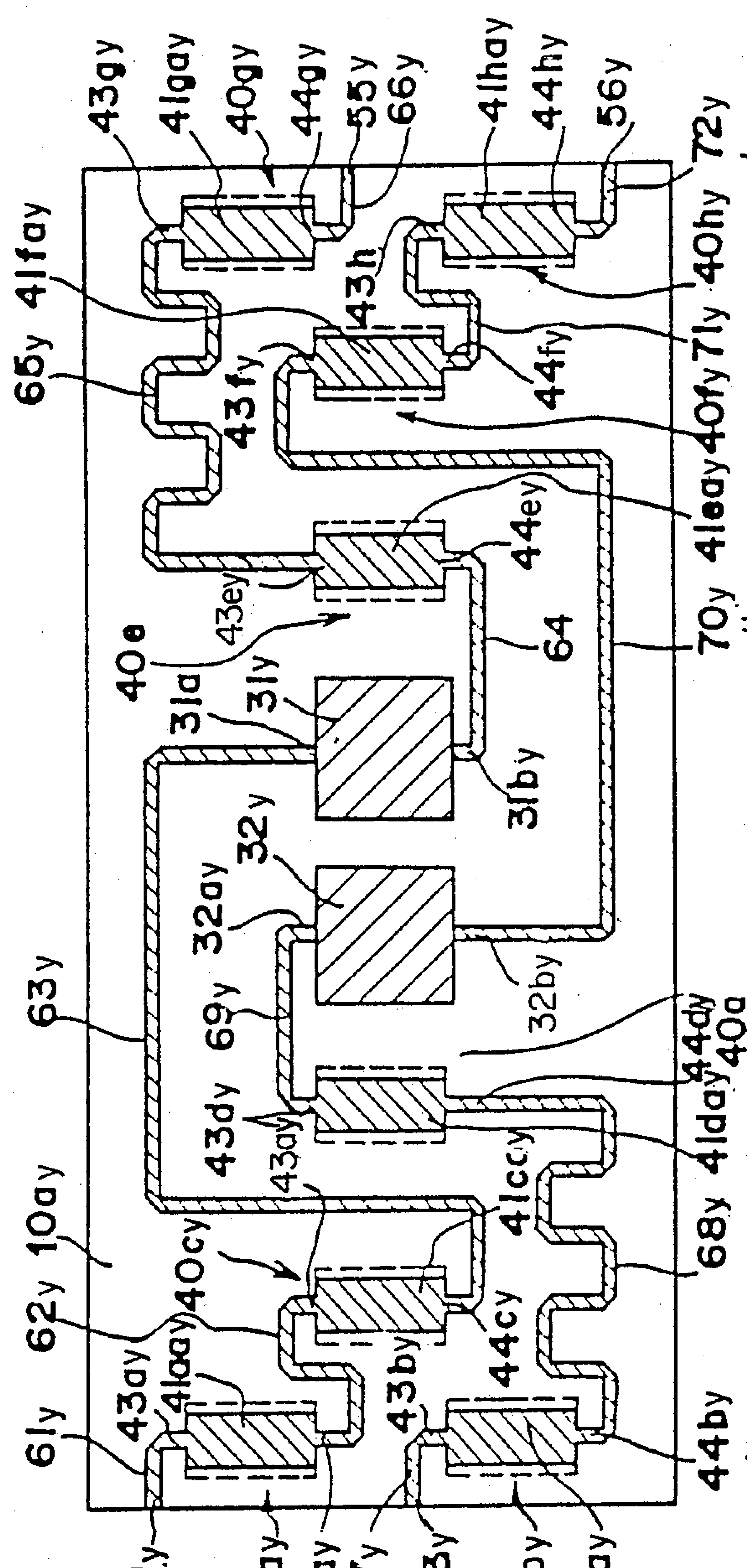


Fig. 18(A)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40gy
44gy
55y
66y
41hay
44hy
56y
72y
41fay
65y
43h
43fy
40hy
71y
44fy
40fy
202y
41eay
44ey
43ey
40e
70y
64
31a
31y
31by
203y
32y
32ay
32by
63y
69y
44dy
40a
43dy
43ay
41day
41ccy
10ay
40cy
62y
68y
201y
44cy
43ay
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43by
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44by
51y
40ay
44ay
67y
53y
40by
41bay

Fig. 18(B)

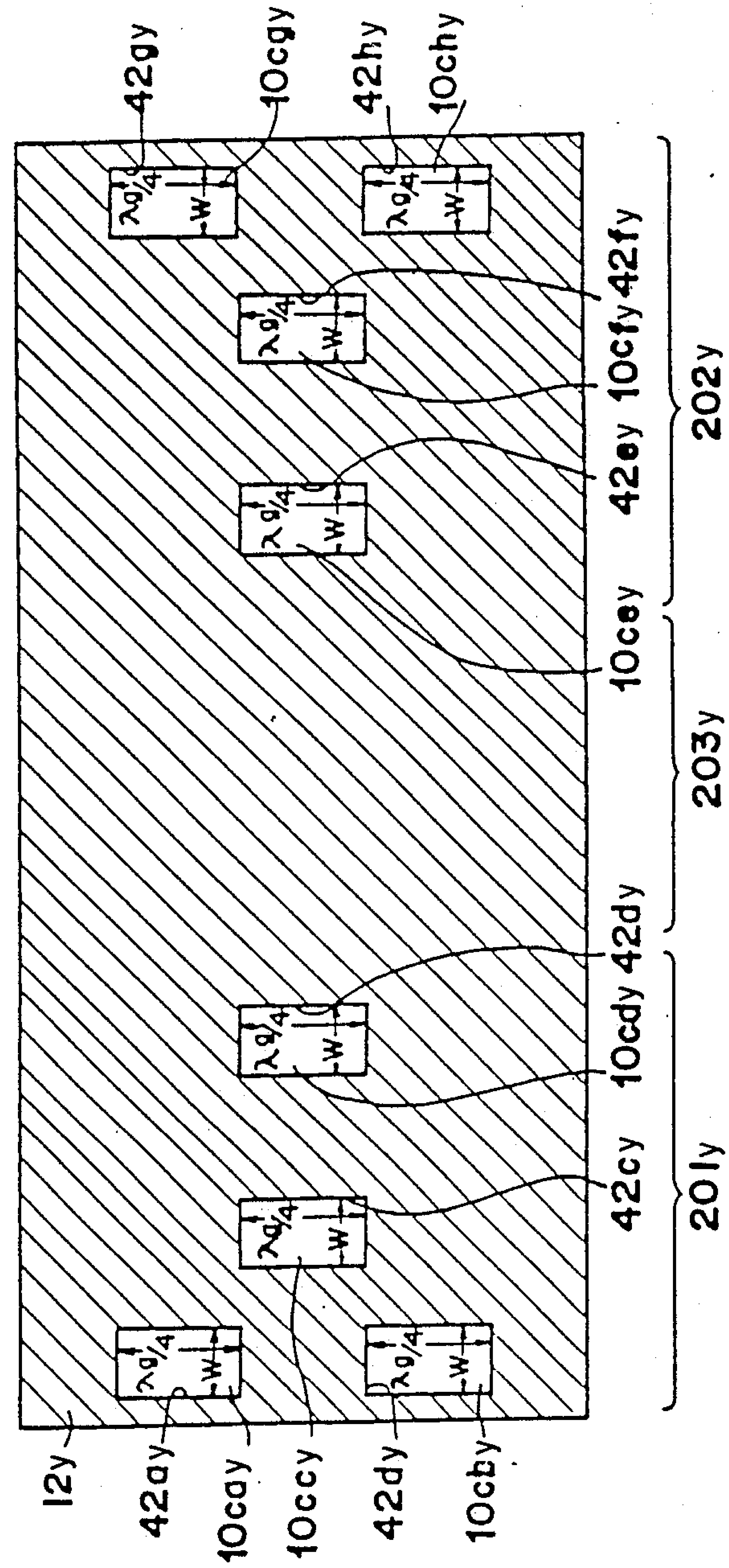
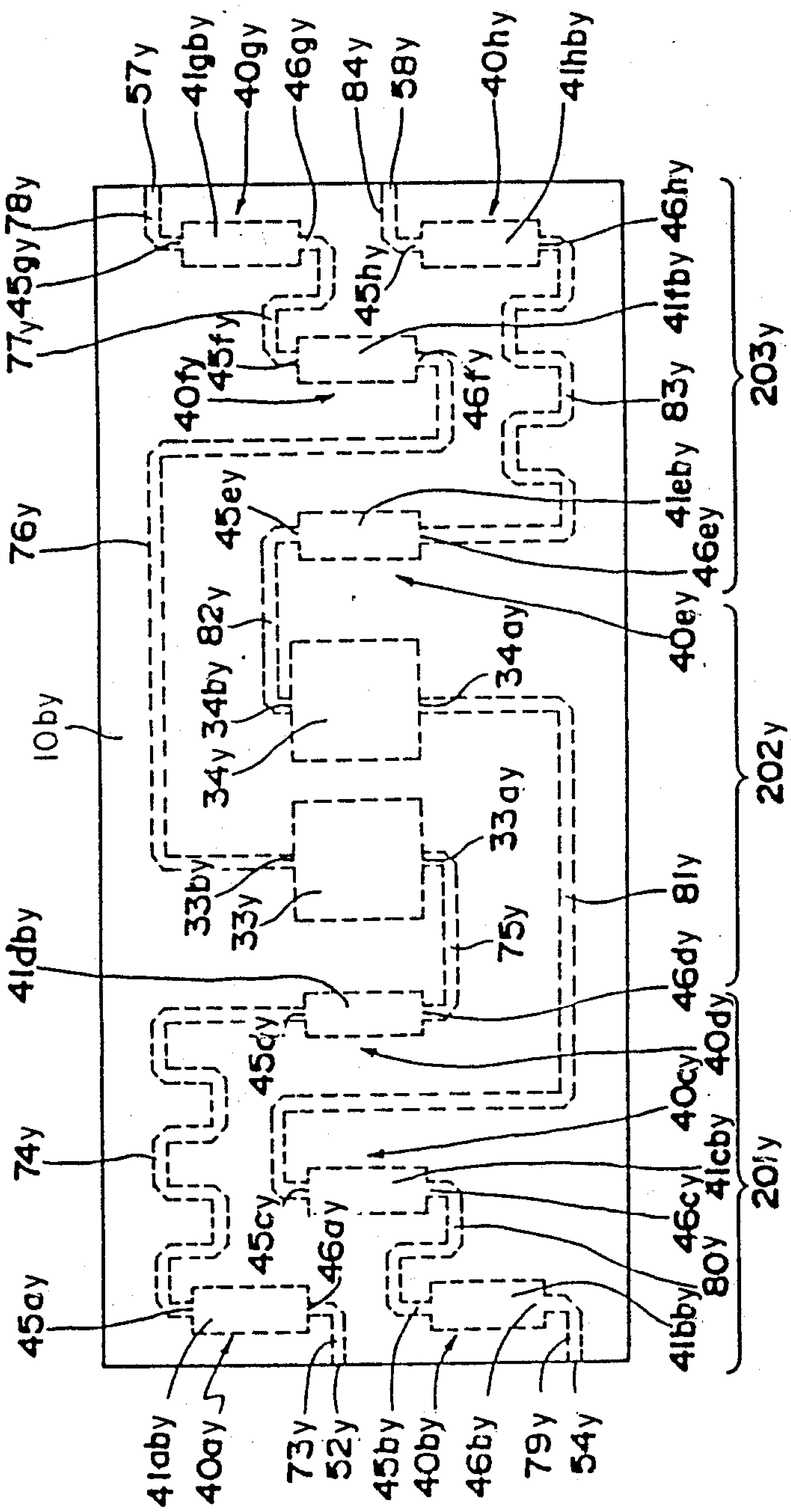

42gy
10cgy
42hy
10chy
42fy
10cfy
42ey
10cey
42dy
10cdy
42cy
202y
203y
201y
12y
42ay
10cay
10ccy
42dy
10cby
W
λg/4

Fig. 18 (C)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41gby
40gy
46gy
84y
58y
40hy
41hby
77y
45gy
78y
45hy
46hy
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40fy
46fy
83y
203y
76y
45ey
41eby
46ey
82y
40ey
10by
34by
34ay
34y
202y
33ay
33by
33y
75y
81y
41dby
46dy
45dy
40dy
40cy
74y
41cby
45cy
46cy
201y
46ay
80y
45ay
41bby
41aby
40ay
73y
52y
45by
40by
46by
79y
54y

DIRECTIONAL COUPLER DEVICE

FIELD OF THE INVENTION

The present invention relates to a directional coupler device.

DESCRIPTION OF THE PRIOR ART

FIG. **3** shows a circuit diagram for a multi terminal directional coupler having four input terminals and four output terminals. In FIG. **3**, the signals input to signal input terminals **1** and **2** are inputted to a hybrid directional coupler **9*a*** having a 3 dB degree of coupling (referred to as coupling degree hereinafter) and each of the signals is divided into two parts by the directional coupler **9*a*** and the divided signals are coupled. The divided and coupled signals are respectively input to hybrid directional couplers **9*c*** and **9*d***. The signals input to the signal input terminals **3** and **4** are inputted to a hybrid directional coupler **9*b*** having a 3 dB coupling degree and each signal is divided into two parts by the directional coupler **9*b*** and each signal is coupled. The divided and coupled signals are input to the hybrid directional couplers **9*c*** and **9*d*** having a 3 dB coupling degree. The signals input in the directional couple **9*c*** are respectively divided in two parts and the signals are coupled. The divided and coupled signals are output at signal output terminals **5** and **6**. The signals input in the directional coupler **9*d*** are respectively divided into two parts and the signals are coupled. The divided and coupled signals are output at the signal output terminals **7** and **8**.

In the multi terminal directional coupler constructed as mentioned above, each signal has ¼ power of the input power of the signals input in the input terminals **1** to **4** and each signal is output at the output terminals **5** to **8**. The multi terminal directional coupler can be applied to a butler matrix which controls the direction of the radiation beam and the available scope of the coupler is wide.

In FIGS. **4**(A) and **4**(B), there is provided a branch line directional coupler **9*a*** on the top surface of the left upper portion of a dielectric substrate **10** which is formed in a rectangular shape having a ground conductor plate **11** formed on the entire reverse surface of the substrate **10**. The branch line directional couple **9*a*** includes strip conductors **21** and **22** having a rectangular shape of a width d1 and a length $\lambda g/4$ and strip conductors **23** and **24** having a rectangular shape of a width d2 and a length $\lambda g/4$. The strip conductors **21** and **22** and the strip conductors **23** and **24** are respectively formed in parallel on the dielectric substrate **10** for providing the respective strip conductors **21** to **24** in a rectangular shape. λg is a wave length in the wave guide. Respective conductors on the connection point of the strip conductors **21** and **23**, the connection point of the strip conductors **22** and **24**, and the connection point of the strip conductors **21** and **24** are respectively indicated by the numeral **25** to **28**. As known in the prior art, in the branch line directional coupler **9*a***, a microwave line of a specific impedance Z_0 may be coupled to the conductors **25** to **28** by suitably defining the widths d1 and d2 of the strip conductors **21** to **24** for obtaining a 3 db coupling degree in a circuit formed by the conductors **25** to **28** of the connection points.

Branch line directional couplers **9*b***, **9*c***, and **9*d*** are formed on the left bottom portion, the right top portion, and the right bottom portion of the top surface of the insulator substrate **10**, as shown in FIG. **4**(A). Branch line directional couplers **9*b***, **9*c***, and **9*d*** are similar to the branch line directional coupler **9*a***. For convenience, reference numerals **21** to **29** of the directional coupler **9*a*** are used in the directional couplers **9*b***, **9*c***, and **9*d***.

The respective conductors **25**, **26**, **27**, and **28** at the connection points of the directional coupler **9*a*** are connected to the signal input terminals **1** and **2**. The connection points **25** of the respective directional couplers **9*c*** and **9*d*** are connected thereto through the connection strip conductors **31**, **32**, **35**, and **36**, having width d. The respective conductors **25**, **26**, **27**, and **28** at the connection points of the direction coupler **9*b*** are connected to the signal input terminals **3** and **4**. The connection points **26** of the respective directional couplers **9*c*** and **9*d*** are connected thereto through the connection strip conductors **33**, **34**, **37**, and **38** having the width d. It is noted that the strip conductors **36** and **37** are formed in solid crossing shape, that is, the conductor **37** is laid over the conductor **36** which has an insulator **43** formed in between at a solid cross portion **30**. The conductors **28** and **27** at the connection points of the directional couple **9*c*** are respectively connected to the signal output terminals **5** and **6** through the strip conductors **39** and **40**. The conductors **28** and **27** at the connection points of the directional coupler **9*d*** are respectively connected to the signal output terminals **7** and **8** through the strip conductors **41** and **42**. In order to transfer ¼ power of the signals input in the signal input terminals **1** to **4** to the output terminals **5** to **8** with a predetermined phase difference, the respective lengths of the connection strip conductors **31** to **34**, **35** to **38**, and **39** to **42** are made equal.

In the multi terminal directional coupler, constructed as mentioned, the connection strip conductors **31** to **42** act as micro strip lines in association with the ground conductor **11** and operate in a similar manner as the directional coupler shown in FIG. **3**. When the specific impedance of the micro strip line is given, the width of the strip conductors **31** to **42** can be selected in a known manner.

In the conventional directional coupler, as shown in FIGS. **4**(A) and **4**(B), the signal which propogates along the strip conductor **36** and the signal which propogates along the strip conductor **36** and the signal which propogates along the strip conductor **37** interfere each other at the cross point **30** of the connection strip conductors **36** and **37**. Whereby, equivalent signals cannot be produced at the signal output terminals **5** to **8**.

In the multi terminal directional coupler, the electrical length of the signals which propogate the connection strip conductors **31**, **35** and **39**; **32**, **36**, and **41**; **33**, **37**, and **40**; **34**, **38**, and **42** from the terminals **1** to **4** to the signal output terminals **5** to **8** are required to coincide. However, in the conventional structure, as shown in FIGS. **4**(A) and **4**(B), it is necessary to adjust the length of the strip conductors **31** to **42** to correspond with the shape of the solid crossing **30**, which makes manufacturing of the coupler difficult.

Furthermore, in order to decrease the electrical coupling among the connection strip conductors **31** to **42** other than the hybrid couplers **9*a*** to **9*d***, it is necessary to make the line distance widths equal. However, in the conventional structure shown in FIG. **4**, there must be provided eight input and output strip conductors **31** to **34** and **39** to **42** and four strip conductors **35** to **38** for connecting the directional couplers on the substrate **10**, whereby the size of the directional coupler is bulky.

The present invention is made for solving the various problems mentioned above by providing directional coupler device which is able to prevent interference of the signals propogating in the strip conductors and to divide the power of the input signal with a good electrical property.

A further object of the present invention is to provide a directional coupler device which is light in weight, compact, and can be manufactured easily.

SUMMARY OF THE INVENTION

The present invention is characterized in that a plurality of first directional couplers are formed on two opposite faces of a ground conductor through dielectric substrates, and two connection conductors are formed on the two opposite faces of the ground conductor through the dielectric substrates. Thereby, an opening is defined in the ground conductor and a plurality of second directional couplers are provided for connecting the conductors.

In the second directional couplers, arranged as mentioned above, the signals on the two connection conductors can be mode-coupled through the opening of the ground conductor. Whereby, the two directional couplers can operate similarly to the conventional branch line directional coupler, as shown in FIGS. 4(A) and 4(B). When first and second micro strip lines formed on the dielectric substrate with two terminals are connected to the connection conductors, the first and second micro strip lines can be coupled by the second directional coupler. Under this condition, a microwave signal input to one signal input terminal of the microstrip line passes the connection conductor of the directional coupler and is output either at another signal terminal of the first microstrip line and at another signal terminal of the second microstrip line. The connection conductor is connected to the first microstrip line. The opening of the ground conductor and the connection conductor are connected to the second microstrip line. A microwave signal input to one signal terminal of the second microstrip line is output at another signal terminal of the first microstrip line in a similar manner, as mentioned above.

In the first directional coupler, which is known as a branch line, interdigit or tandem directional couplers are provided on both faces of the ground conductor through the dielectric substrate and the second directional coupler is connected to the first directional coupler. Whereby, a multi directional coupler having a plurality of input and output terminals may be provided.

Accordingly, the first directional couple can divide each of the input signals. The divided input signals can be coupled and output at the second directional coupler. Subsequently, the second directional coupler divides each of the input signals and couples the divided input signals and outputs. For example, assuming that the multi terminal directional coupler includes two first directional couplers and two second directional couplers with the coupling degree of the first and second directional couplers being 3 db. In a similar manner to the device shown in FIGS. 4(A) and 4(B), the second directional couple outputs $\frac{1}{4}$ power of the input signal that this input to the first directional coupler.

As mentioned above, since the first directional coupler is provided on the opposite faces of the ground conductor through the dielectric substrate, while the connection conductor of the second directional coupler is provided on the dielectric substrate, it is possible to make a multi terminal directional coupler $\frac{1}{2}$ size of the conventional directional coupler and it is not necessary to provide the solid crossing. Accordingly, it is possible to form accurate conductor patterns and to prevent interference of the signals at the solid crossing which occurs in the conventional directional coupler.

Furthermore, the present invention is characterized in that a multi terminal directional couple includes N input terminals, wherein N is 2^l with N being more than 4 and is a natural number, N output terminals and $l \times 2^{l-1}$ directional couplers for outputting signals having 1/N power from the input signals which are input to the N input terminals. Each of the $l \times 2^{l-1}$ directional couplers is formed in such a manner that two coupling conductors forming the output or input terminals are formed on two opposite sides of a ground conductor through dielectric substrates and two opposite coupling conductors are electromagnetically coupled through an opening defined in the ground conductor.

By the arrangement mentioned above, strip conductors for connecting the input terminals, the output terminals, coupling conductors of the directional couplers, the respective terminals and coupling conductors, and the respective conductors can be separated formed on the respective dielectric substrates situated on both sides of the multi terminal directional coupler may be decreased to about $\frac{2}{3}$ of the conventional directional coupler. Whereby, it is possible to decrease the size and weight of the directional coupler. Moreover, since the solid crossing can be eliminated, it is possible to prevent the interference between the signals propogating in the strip conductors. Therefore, multi terminal directional couplers can be provided which are able to divide the power of the input signals with a good electrical property.

Moreover, according to the present invention, there is provided a microwave signal processing circuit which includes a directional coupler formed in such a manner that a pair of coupling conductors forming input and output terminals are formed on both sides of a ground conductor through substrates. Thereby, the coupling conductors are electromagnetically coupled through an opening defined on a ground conductor formed between the coupling conductors and the microwave signal processing circuit disposed on the substrates connected at the front stage or the rear stage of the directional coupler.

In the arrangement mentioned above, the coupling conductors of the directional coupler, the microwave signal processing circuits, the connecting lines for connecting the coupling conductors, and the microwave signal processing circuits may be divided in two parts on both sides of the two substrates. Accordingly, the size of the microwave device can be decreased by $\frac{1}{2}$, as compared to the conventional device and it is possible to decrease the size and weight of the microwave device. In additional, since the device, according to the present invention, can be made without ridge coupling, as used in the conventional device, it is possible to prevent the interference between the signals propogating in the various circuits or lines of the device. Therefore, there can be provided microwave devices which can process the input signals with a good electric property.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitative of the present invention, and wherein:

FIG. 1(A) is a top plan view showing an example of a four input and four output directional coupler according to an embodiment of the present invention;

FIG. 1(B) is a plan view showing the directional coupler of FIG. 1(A), as viewed from below;

FIG. 1(C) is a top plan view showing a ground conductor used in the directional coupler of FIG. 1(A);

FIG. 1(D) is a cross sectional view taken along the line A—A' of FIG. 1(A) and FIG. 1(B);

FIGS. 2(A) and 2(B) are vertical cross sectional views showing an electric field distribution for even and odd modes in a vertical mode drive at the connecting portion of the line B—B' of FIGS. 1(A) and 1(B);

FIG. 3 is a circuit diagram of the four input and four output multi terminal directional coupler of FIGS. 1(A) and 1(B);

FIG. 4(A) is a top plan view showing a four input and four output multi terminal directional coupler using four branch line directional couplers;

FIG. 4(B) is a vertical cross sectional views taken along the line C—C' of FIG. 4(A);

FIG. 5(A) is a top plan view showing an example of the four input and four output multi terminal directional coupler according to another embodiment of FIG. 4(A);

FIG. 5(B) is a bottom plan view of the multi terminal directional coupler of FIG. 5(A);

FIG. 5(C) is as vertical cross sectional view taken along the line A—A' shown in FIGS. 5(A) and 5(B);

FIG. 5(D) is a vertical cross sectional view taken along the line B—B' of FIGS. 5(A) and 5(B);

FIG. 6(A) is a top plan view showing the multi terminal directional coupler of FIG. 5(A);

FIG. 6(B) is a top plan view of a ground conductor used in the multi terminal directional coupler of FIG. 5(A);

FIG. 6(C) is a top plan view showing conductor patterns of the bottom surface of the multi terminal directional coupler of FIG. 5(A);

FIG. 7(A) is a top plan view showing another example of the directional coupler forming the rear part of an eight input and an eight output multi terminal directional coupler;

FIG. 7(B) is a top plan view showing a ground conductor of the directional coupler of FIG. 7(A);

FIG. 7(C) is a top plan view of the conductor patterns of the directional coupler of FIG. 7(A);

FIG. 8(A) is a circuit diagram of the multi terminal directional coupler of FIGS. 5(A) to 5(D);

FIG. 8(B) is a circuit diagram showing a modification of the multi terminal directional coupler of FIGS. 5(A) to 5(D);

FIG. 9 is a circuit diagram showing the multi terminal directional coupler of FIG. 7(A) to 7(C);

FIGS. 10(A) and 10(B) are vertical cross sectional views for even and odd modes of the vertical mode drive at the connecting portion on the line F—F' of FIGS. 5(A) and 5(B);

FIG. 11 is a circuit diagram showing the conventional four input and four output multi terminal directional coupler;

FIG. 12 is a circuit diagram showing the conventional eight input and eight output multi terminal directional coupler;

FIG. 13 is a circuit diagram showing the conventional sixteen input and sixteen output multi terminal directional coupler;

FIG. 14(A) is s top plan view showing the four input and four output multi terminal directional coupler using a four branch line directional coupler;

FIG. 14(B) is a vertical cross sectional view taken along the line E—E' of FIG. 14(A);

FIG. 15(A) is a top plan view showing a microwave balanced amplifier according to an embodiment of the present invention;

FIG. 15(B) is a top plan view of the ground conductor used in the microwave balanced amplifier of FIG. 15(A);

FIG. 15(C) is a top plan view showing the conductor patterns used in the microwave balanced amplifier of FIG. 15(A);

FIG. 15(D) is a vertical cross sectional view taken along the line A—A' of FIG. 15(A);

FIG. 15(E) is a vertical cross sectional view taken along the lines of B—B' of FIG. 15(A);

FIGS. 16(A) and 16(B) are vertical cross sectional views showing the electric field distribution for odd and even modes of the vertical drive at the connecting portion of the line B—B' of FIG. 15(A);

FIG. 17 is an embodiment of a four input and a four output multi terminal amplifier according to the present invention;

FIG. 18(A) is a top plan view of the multi terminal amplifier for showing the practical feature of the multi terminal directional coupler of FIG. 17;

FIG. 18(B) is a top plan view of the ground conductor 12 of the multi terminal amplifier of FIG. 17; and

FIG. 18(C) is a top plan view showing the conductor patterns on the dielectric substrate 10*by* used in the multi terminal amplifier of FIG. 17.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1(A) to 1(D), there are defined coupling openings 17*a* and 17*b* which penetrate a ground conductor 11 and have a length W on the short side and a length $\lambda g/4$ on the long side in the upper right portion and the lower right portion of an elongated ground conductor 11 which has a thickness of t0. The coupling openings 17*a* and 17*b* are filled with coupling insulation materials 10*ca* and 10*cb*. The ground conductor 11 is provided between dielectric substrates 10*a* and 10*b* which have thickness of t.

In the upper right portion of FIG. 1(A) above the dielectric substrate 10*a*, a coupling conductor 18*a* of a rectangular shape with a length S on the short side and a length $\lambda g/4$ on the along side is formed above the coupling insulation material 10*ca*. On the other hand, another coupling conductor 19*a*, similar to the conductor 18*a*, is formed below the coupling insulation material 10*ca* in the upper left portion of FIG. 1(B) on the lower surface of the dielectric substrate 10*b*. In order to provide input terminals and output terminals of the multi terminal directional coupler on the same side and to equalize the electric length between the input terminals and the output terminals, the coupling conductors 18*a* and 19*a* are formed so that the longitudinal directions of the coupling conductors 18*a* and 19*a* extend in a parallel direction to the longitudinal direction of the dielectric substrates **10***a* and **10***b*. When a microwave signal is applied to the ends of the short sides of the coupling conductors **18***a* and **19***a*, there is developed a mode coupling between the coupling conductors **18***a* and **18***b* and the ground conductor **11** through the coupling insulation material **10***ca* in the coupling opening **17***a*. Then, the input power is divided into two equivalent parts and the input power is coupled. Thereby, the power is output at the other end of the short side of each of the coupling conductors **18***a* and **19***a*.

Referring to FIGS. **1**(A) and **1**(B), the positions of the coupling openings **17***a* and **17***b* are indicated by the dotted lines. The respective short sides of the coupling opening **17***a* of the ground conductor **11** and the short sides of the coupling conductors **18***a* and **19***a* coincide with each other. The dielectric substrates **10***a* and **10***b* and the coupling insulation material **10***ca* are formed in one body having the same dielectric constant.

FIGS. **2**(A) and **2**(B) are respectively vertical cross sectional views showing the electric field distribution of the odd mode an the even mode by the known vertical mode driving at the coupling portion on the B—B' line of FIGS. **1**(A) and **1**(B). In the even mode, which is shown in FIGS. **2**(A), electric force lines are developed between the coupling conductors **18***a* and **19***a* and the ground conductor **11**, whereby the opening acts as a magnetic wall. On the other hand, in the odd mode, which is shown in FIG. **2**(B), electric force lines are developed between the coupling conductors **18***a* and **19***a* and the ground conductor **11**, whereby the opening acts as an electric wall.

Accordingly, a directional coupler **9***ca* is formed having a predetermined coupling degree by the ground conductor **11** and the coupling conductors **18***a* and **19***a* are formed on the dielectric substrates **10***a* and **10***b*. Therefore, a four terminal directional coupler **9***ca* may be provided having a coupling degree of 3 dB by selecting the dielectric constant of the dielectric substrate **10***a*, the width S of the coupling conductors **18***a* and **19***a*, and the width W of the coupling opening **17***a*. It is noted that the coupling degree is 3 dB. In order to increase the coupling degree, the width W of the coupling opening **17***a* is made large.

There is formed a coupling conductor **18***b* having the same shape of the conductor **18***a* directly above the coupling insulation material **10***cb* in the lower right portion in FIG. **1**(A) on the dielectric substrate **10***a*. Also, a coupling conductor **19***b* is formed having the same shape as the conductor **19***a* directly below the coupling insulation material **10***cy* in the lower left portion of FIG. **1**(B) on the lower surface of the dielectric substrate **10***b*. Accordingly, there can be provided a directional coupler **9***da* having a 3 dB coupling degree in a similar manner as the directional coupler **9***ca* using the ground conductor **11** and the coupling conductors **18***b* and **19***b*.

There is formed a branch line directional coupler **9***a* having a 3 dB coupling degree similar to a conventional coupler at the central portion of FIG. **1**(A) on the upper surface of the dielectric substrate **10***a*. Another branch line directional coupler **9***b* having a 3 dB coupling degree similar to a conventional coupler is formed at the central portion of FIG. **1**(B) on the lower surface of the dielectric substrate **10***b*.

On the upper surface of the dielectric substrate **10***a*, the signal input terminals **1** and **2** are connected to the conductors **25** and **26** disposed at the connection points of the directional coupler **9***a* through connection strip conductors **31** and **32** having a width of d. The connection conductors **27** and **28** of the directional coupler **9***a* are connected on the lower end of the short side of the coupling conductor **18***a* of the directional coupler **9***ca* and the short side of the coupling conductor **18***b* of the directional coupler **9***da* through connecting strip conductors **36** and **35**. The upper end portion of the short side of the coupling conductor **18***a* of the directional coupler **9***ca* and the lower end portion of the short side of the coupling conductor **18***b* of the directional coupler **9***da* are connected to the signal output terminals **5** and **7** through connecting strip conductors **39** and **41**.

On the lower surface of the dielectric substrate **10***b*, the signal input terminals **3** and **4** are connected to conductors **25** and **26** at the connection point of the directional coupler **9***b* through the connection strip conductors **33** and **34** having a width of d. Conductors **27** and **28** at the connecting point of the directional coupler **9***b* are connected to the upper end portion on the short side of the coupling conductor **19***a* of the directional coupler **9***ca* and the lower end portion on the short side of the coupling conductor **19***b* of the directional coupler **9***da* through the connection strip conductors **38** and **37** having a width of d. The lower end portion on the short side of the coupling conductor **19***a* of the directional coupler **9***ca* and the upper end portion on the short side of the coupling conductor **19***b* of the directional coupler **9***da* are connected to the signal output terminals **6** and **8** through the connection strip conductors **40** and **42**. In the arrangement mentioned above, the signal input terminals **1** and **2** and the signal output terminals **5** and **7** are formed on the outer parts of the left and right side of the dielectric substrate **10***a*. The signal input terminals **3** and **4** and the signal output terminals **6** and **8** are formed on the outer parts of the left and right sides of the dielectric substrate **10***b*. Therefore, when lead wires are connected to the signal input terminals and the signal output terminals, the connection of the lead wires is easy since the connecting positions do not overlap.

Moreover, in order to transmit $\frac{1}{4}$ power of the input signals entered at the signal input terminals **1** to **4** to the signal output terminals **5** to **8** with the same phase difference of the input signals, the electric lengths of the parts beginning from the signal input terminals **1** to **4** to the input ends of the respective directional couplers **9***ca* and **9***da* including connection strip conductors **31** and **35**, connection strip conductors **32** and **36**, connection strip conductors **33** and **37** and connection strip conductors **34** and **38** are equivalent. Also, the electric lengths of the parts beginning from the output ends of the directional couplers **9***ca* and **9***da* including the connection strip conductors **39** to **42** are equivalent.

The multi terminal directional coupler, arranged as mentioned above, has an equivalent circuit to the circuit of FIG. **3** and can act similar to the circuit of FIGS. **4**(A) and **4**(B). Although in the embodiment mentioned above the terminals **1** to **4** are used as the signal input terminals and the terminals **5** to **8** are used as the signal output terminals, the multi terminal directional coupler can act as a reversible circuit. Therefore, the terminals **1** to **4** can be used as the signal output terminals and the terminals **5** to **8** can be used as the signal input terminals.

In the arrangement shown in the present arrangement, it is possible to decrease the sides of the device to about $\frac{1}{2}$ of the conventional device of FIGS. **4**(A) and **4**(B). In addition, since the solid crossing part **30** formed by the strip conductors **36** and **37**, as shown in FIGS. **4**(A) and **4**(B) is unnecessary, the input signal can be divided into two parts having equal power and good equivalency. In addition, since the solid crossing part **30** is unnecessary in the present embodiment, it is possible to form the conductor patterns accurately, whereby, the electric lengths between the respective input terminals and output terminals can be made uniformly. Accordingly, an accurate phase relation can be assured between the input terminal an the output terminal.

In the embodiment mentioned above, although the branch line hybrid directional couplers **9***a* and **9***b* are used for dividing and coupling the power of the signal on the same plane, the present invention is not limited to this embodiment. For example, various hybrid directional couplers may be used, such as an interdigit type, and a tandem connection type hybrid directional coupler for dividing and coupling the power of the signal. In this case, it is possible to decrease the sides of the device, as compared to the device using the branch line hybrid directional coupler.

In the embodiment mentioned above, although an explanation is made with respect to the case having four input and four output terminals, the present invention is not limited to this embodiment. The present invention can be applied to the case having multi terminals more than five and there may be arranged such a multi terminal directional coupler having more than three known directional couplers **9***a*, **9***b*, and **9***c*, and more than two directional couplers **9***ca* and **9***da* .

Moreover in the embodiment mentioned above, although the shape of the coupling conductors **18***a*, **18***b*, **19***a*, and **19***b* and the coupling openings **17***a* and **17***b* are rectangular, they are not limited, as shown in this embodiment. It is possible to form the coupling opening for coupling the mode coupling conductors **18***a*, **19***a*, **18***b*, and **19***b*.

In the present invention, there are provided a plurality of first directional couplers on both sides of the ground conductor through the dielectric substrate and two coupling conductors are formed which are connected with the first directional couplers on both sides of the ground conductor through the dielectric substrate. In addition, the ground conductor between the coupling conductors is provided by the opening. Moreover, there are provided the second directional couplers to couple the coupling conductors, whereby the second directional couplers act in a similar manner as the conventional branch line directional couplers as shown in FIGS. 4(A) and 4(B), so that there are provided two known first directional couplers and second directional couplers. Therefore, the multi terminal directional coupler, according to the present invention, can act similar to the conventional directional coupler.

As mentioned above, the first directional couplers are provided on both sides of the ground conductors through the dielectric substrates. The coupling conductors of the second directional coupler are provided on the dielectric substrates and a multi terminal directional coupler having ½ size of the conventional multi terminal directional coupler can be formed to eliminate the solid crossing. Accordingly, the conductor patterns of the directional coupler can be formed accurately, it is advantageous that the signals can be output with a good electric property for preventing the interference of the signals at the solid crossing part.

A further embodiment of the present invention is explained hereinafter.

Referring to FIGS. 5(A), 5(B), 6(A), and 6(B), there are defined coupling openings **52***ax* to **52***dx* which penetrate a ground conductor **11***x* and have a length W on the short side and a length λg/4 on the long side in the upper left portion, the lower left portion, the central portion, and the central right portion of an elongated ground conductor **11***x* having a thickness. The coupling openings **52***ax* to **52***dx* are filled with coupling insulation materials **10***cax*, **10***cbx*, **10***ccx*, and **10***cdx*. The ground conductor **11***x* is provided between dielectric substrates **10***ax* and **10***bx*.

In the upper left portion of FIG. 5(A) above the dielectric substrate **10***ax*, a coupling conductor **51***aax* having a rectangular shape of a length S on the short side and a length λg/4 on the long side is formed above the coupling insulation material **10***cax*. On the other hand, another coupling conductor **51***abx* similar to the conductor **51***aax* is formed below the coupling insulation material **10***cax* on the upper right portion of FIG. 5(B) on the lower surface of the dielectric substrate **10***bx*. In order to provide input terminals and output terminals of the multi terminal directional coupler on the same side and to equalize the electrical length between the input terminal and the output terminal, the coupling conductors **51***aax* and **51***abx* are formed so that the longitudinal directional of the coupling conductors **51***aax* and **51***abx* extend in a parallel direction to the longitudinal direction of the dielectric substrates **10***aax* and **10***abx*. When a microwave signal is applied to the ends of the short sides of the coupling conductors **51***aax* and **51***abx*, there is developed a mode coupling between the coupling conductors **51***aax* and **51***abx* and the ground conductor **11***x* through the coupling insulation material **10***cax* in the coupling opening **52***ax*. Then, the input power is divided into two equivalent parts and the power is coupled. Thereby, power is output at the other end of the short side of each of the coupling conductors **51***aax* and **51***abx*.

Referring to FIGS. 5(A) and 5(B), the positions of the coupling openings **52***ax* and **52***dx* are indicated by dotted lines. The respective short sides of the coupling opening **52***ax* of the ground conductor **11***x* and the short sides of the coupling conductors **51***aax* and **51***abx* coincide with each other. The dielectric substrates **10***ax* and **10***bx* and coupling insulation material **10***cax* are formed in one body having the same dielectric constant. The same structure may be employed in the directional couplers **50***bx* to **50***dx*.

FIGS. 10(A) and 10(B) are respectively vertical cross sectional views showing the electric field distribution of odd and even modes from a known vertical mode driving at the coupling portion on the F—F′ line of FIG. 5. In the even mode, which is shown in FIG. 10(A), there are developed electric force lines between the coupling conductors **51***aax* and **51***abx* and the ground conductor **11***x*, whereby, the opening acts as a magnetic wall. On the other hand, in the odd mode, which is shown in FIG. 10(B), there are developed electric force lines between the coupling conductors **51***aax* and **51***abx* and the ground conductor **11***x*, whereby the opening acts as an electric wall.

Accordingly, a directional coupler **50***ax* having a predetermined coupling degree is formed by the ground conductor **11***x* and the coupling conductors **51***aax* and **51***abx* are formed on the dielectric substrates **10***ax* and **10***bx*. Therefore, there can be provided a four terminal directional coupler **50***ax* having a coupling degree of 3 dB by selecting the dielectric constant of the dielectric substrates **10***ax* and **10***bx*, the width S of the coupling conductors **51***aax* and **51***abx* and the width W of the coupling opening **52***ax*. It is noted that the coupling degree is 3 dB. In order to increase the coupling degree, the width W of the coupling opening **52***ax* is made large.

There is formed a coupling conductor **51***bax* having the same shape of the conductor **51***aax* directly above the coupling insulation material **10***cbx* in the lower left portion of FIG. **5**(A) on the dielectric substrate **10***ax*. A coupling conductor **51***bbx* having the same shape of the conductor **51***abx* is formed directly below the coupling insulation material **10***cbx* in the lower right portion in FIG. **5**(B) on the lower surface of the dielectric substrate **10***bx*. Accordingly, there can be provided a directional coupler **50***bx* having a 3 dB coupling degree in a similar manner as the directional coupler **50***ax* by the ground conductor **11***x* and the coupling conductors **51***bax* and **51***bbx*.

There is formed a coupling conductor **51***cax* having the same shape of the conductor **51***aax* directly above the coupling insulation material **10***cdx* at the right central portion of FIG. **5**(A) on the dielectric substrate **10***ax*. A coupling conductor **51***dbx* having the same shape of the conductor **51***abx* is formed directly below the coupling insulation material **10***cdx* at the left central portion of FIG. **5**(B) on the lower surface of the dielectric substrate **10***bx*. Accordingly, there can be provided a directional coupler **50***dx* having a 3 dB coupling degree in a similar manner as the directional coupler **50***ax* by the ground conductor **11***x* and the coupling conductors **51***dac* and **51***dbx*.

On the upper surface of the dielectric substrate **10***ax*, the signal input terminal **1***x* is connected to the connection terminal **56***ax* on the upper portion of the coupling conductor **51***aax* of the directional coupler **50***ax* through a connection strip conductor **61***x*. The connection terminal **57***ax* on the lower portion of the coupling conductor **51***aax* of the directional coupler **50***ax* is connected to the connection terminal **56***cx* on the upper portion of the coupling conductor **51***cax* of the directional coupler **50***cx* through a connection strip conductor **63***x* having a S shape. The connection terminal **57***cx* on the lower portion of the coupling conductor **51***cax* of the directional coupler **50***cx* is connected to the signal output terminal **5***x* through the connection strip conductor **65***x*. The signal input terminal **2***x* is connected to the connection terminal **56***bx* on the upper portion of the coupling conductor **51***bax* of the directional coupler **50***bx* through the connection strip conductor **62***x*. The connection terminal **57***bx* on the lower portion of the coupling conductor **51***bax* of the directional coupler **50***bx* is connected to the connection terminal **57***dx* of the coupling conductor **51***dax* of the directional coupler **50***dx* through the connection strip conductor **64***x* having a zigzag shape. The connection terminal **56***dx* in the upper portion of the coupling conductor **51***dax* of the directional coupler **50***dx* is connected to the signal output terminal **6***x* through the connection strip conductor **66***x*.

On the lower surface of the dielectric substrate **10***bx*, the signal input terminal **3***x* is connected to the connection terminal **59***ax* on the lower portion of the coupling conductor **51***abx* of the directional coupler **50***ax* connection terminal **58***ax* in the upper portion of the coupling conductor **51***abx* of the directional coupler **50***ax* is connected to the connection terminal **58***dx* in the upper portion of the coupling conductor **51***dbx* of the directional coupler **50***dx* through the connection strip conductor **73***x* having a zigzag shape. The connection terminal **59***bx* in the lower portion of the coupling conductor **51***dbx* of the directional couple **50***dbx* is connected to the signal output terminal **7***x* through the connection strip conductor **75***x*. The signal input terminal **4***x* is connected to the connection terminal **59***bx* in the lower portion of the coupling conductor **51***bbx* of the directional coupler **50***bx* through the connection strip conductor **72***x*. The connection terminal **58***dx* on the upper portion of the coupling conductor **51***bbx* of the directional coupler **50***bx* is connected to the connection terminal **59***cx* in the lower portion of the coupling conductor **51***cbx* of the directional coupler **50***cx* through the connection strip conductor **74***x* having an S shape. The connection terminal **58***cx* in the upper portion of the coupling conductor **51***cbx* of the directional coupler **50***cx* is connected to the signal output terminal **8***x* through the connection strip conductor **76***x*.

The width of the respective connection strip conductors **61***x* to **66***x* and **71***x* to **76***x* are defined according to the characteristic impedance.

As shown in FIGS. **5**(A) and **5**(B), the signal input terminals **1***x* to **4***x* and the signal output terminals **5***x* to **8***x* are formed so that they are located alternatively on the dielectric substrates **10***ax* and **10***bx* with the different position of one side of the dielectric substrates **10***ax* and **10***bx*. Accordingly, in order to connect a lead wire to the respective signal input and output terminals **1***x* to **8***x*, the respective connection points do not overlap so that the work connection is easy. In order to output a signal having $\frac{1}{4}$ power of the input signal applied to the signal input terminals **1***x* to **4***x* at the respective output terminals **5***x* to **8***x* with the same phase difference, the electric length of the connection strip conductor beginning from the respective signal input terminals **1***x* to **4***x* and ending at the signal output terminals **5***x* to **8***x* through the respective directional couplers. That is, the electric length is the total electric length of the connection strip conductors **61***x*, **63***x* and **65***x*; the total electric length of the connection strip conductors **62***x*, **64***x* and **66***x*; the total electric length of the connection strip conductors **71***x*, **73***x* and **75***x*; and the total electric length of the connection strip conductors **72***x*, **74***x* and **76***x* are made uniform.

The multi terminal directional coupler as mentioned above is equivalent to the circuit **100***x* of FIG. **1**, and can operate in the same manner as the coupler of FIGS. **14**(A) and **14**(B). In the embodiment mentioned above the terminals **1***x* to **4***x* are used as the signal input terminal and the terminals **5***x* to **8***x* are used as the output terminals. However, the multi terminal directional coupler according to the present invention is a reversible circuit. Therefore, terminals **1***x* to **4***x* may be used as the signal output terminals and terminals **5***x* to **8***x* may be used as the signal input terminals.

In the arrangement of this embodiment, four directional couplers **50***ax* to **50***dx* are used with the two directional couplers **50***ax* and **50***bx* juxtaposed on the upper portion and the lower portion of FIGS. **6**(A) to **6**(C) and two directional couplers **50***cx* and **50***dx* juxtaposed on the left portion and the right portion of FIGS. **6**(A) and **6**(C). Therefore, the size of the multi terminal directional coupler **60***x* can be decreased about $\frac{2}{3}$ compared to a conventional coupler as shown in FIGS. **14**(A) and **14**(B). Since the solid crossing **30***x* formed by the strip conductor **37***x* as shown in FIGS. **14**(A) and **14**(B) can be eliminated, the input signal can be divided into equivalent power having a good uniformity. In this embodiment, since the solid crossing **30***x* is eliminated, the circuit patterns can be made accurately and the electric lengths between the input and output terminal can be made uniform. Therefore there can be obtained an accurate phase relation at the input terminal and the output terminal. The conductor patterns on the dielectric substrate of FIG. 5(A) is equivalent to the patterns that are reversed by 180° from the conductor pattern on the dielectric substrate **10***b* and the two conductor patterns can be formed by the same pattern.

FIG. 8(A) is a circuit diagram of a multi terminal directional coupler **60***x* wherein the connection strip conductors formed on the top surface and the lower surface of the multi terminal directional coupler **60***x* of FIGS. 5(A) to 5(B) are separately shown. In FIG. 8(A), the real lines in the connection line and the directional coupler show the connection conductors **51***aax*, **51***bax*, **51***cax* and **51***dax* formed on the dielectric substrate **10***ax* and the connection strip conductors **61***x* to **66***x*. The dotted lines in the connection lines and the directional coupler show the connection conductors **51***abx*, **51***bbx*, **51***cbx* and **51***dbx* and the connection strip conductors **71***x* to **76***x*. As shown in FIG. 8(A), the directional coupler **50***cx* may be located as shown in FIG. 8(B) at the solid crossing position **77***x* on which the connection strip conductors **65***x* and **76***x* cross in a solid manner. The multi terminal directional coupler **61***x* arranged as mentioned above can act in the same manner as the multi terminal directional coupler **60***x* with the same advantage as the multi terminal directional coupler **60***x*.

FIG. 9 is a further example of the multi terminal directional coupler having 8 input terminals and 8 output terminals according to the present invention. The multi terminal directional coupler includes two multi terminal directional couplers **60***x* and **60**'*x* having four input and four output terminals and a directional coupler **80***x* having 8 input terminals and 8 output terminals. The multi terminal directional coupler **60**'*x* is formed in the same manner as the multi terminal directional coupler **60***x* shown in FIGS. 5(A) to 5(D) and includes four signal input terminals l'*x* to **4**'*x* and four signal output terminals **5**'*x* to **8**'*x*. The directional coupler **80***x* includes four directional couplers **50***ex* to **50***hx* having the same structure as the directional couplers **50***ax* to **50***dx*, and act similar to the conventional directional coupler **118***x* of FIG. 8. The signal output terminals **5***x* to **8***x* and **5**'*x* to **8**'*x* are connected to the signal input terminals **81***x* to **88***x* and the multi terminal directional coupler of FIG. 9 acts similar to the conventional multi terminal directional coupler **120***x* of FIG. 12.

FIGS. 7(A) to 7(C) show the specific structure of the directional coupler **80***x* of FIG. 9. In FIGS. 7(A) to 7(C), although there is shown only one directional coupler **80***x*, the directional coupler **80***x* is formed integrally with the two multi terminal directional couplers **60***x* and **60**'*x* on the dielectric substrate **10***ax* and **10***bx*. The structure of the directional coupler **80***x* is explained hereinafter.

In FIGS. 7(A) to 7(C), four coupling conductors **51***eax*, **51***fax*, **51***gax* and **51***hax* having the same shape as the conductor **51***aax* are juxtaposed in left and right directions with the predetermined space in the central portion of the upper surface of the dielectric substrate **10***ax* directly above the coupling dielectric materials **10***cex*, **10***cfx*, **10***cgx* and **10***chx*.

In FIGS. 7(A) to 7(C), four coupling conductors **51***ebx*, **51***fbx*, **51***gbx* and **51***hbx* having the same shape as the conductor **51***abx* are juxtaposed in left and right directions with the predetermined space on the central portion of the upper surface of the dielectric substrate **10***bx* directly below the coupling dielectric materials **10***cex*, **10***cfx*, **10***cgx* and **10***chx*. Accordingly, there is formed a directional coupler **50***ex* having a 3 dB coupling degree being the same as the directional coupler **50***ax* by the coupling conductors **51***eax* and **51***ebx* and the ground conductor **11***x*. There is formed a directional coupler **50***fx* having a 3 dB coupling degree the same as the directional coupler **50***ax* by the coupling conductors **51***fax* and **51***fbx* and the ground conductor **11***x*. There is formed a directional coupler **50***gx* having a 3 dB coupling degree the same as the directional coupler **50***ax* by the conductors **51***gax* and **51***gbx* and the ground conductor **11***x*. There is formed a directional coupler **50***hx* having a 3 dB coupling degree the same as the directional coupler **50***ax* by the coupling conductors **51***hax* and **51***hbx* and the ground conductor **11***x*.

On the top surface of the dielectric substrate **10***ax*, as shown in FIG. 7(A), the signal input terminal **81***x* is connected to the connection terminal **56***hx* in the upper portion of the coupling conductor **51***hax* of the directional coupler **50***hx* through a connection strip conductor **201***x* having a zigzag shape. The connection terminal **57***hx* on the lower portion of the coupling conductor **51***hax* of the directional coupler **50***hx* is connected to the signal output terminal **89***x* through the connection strip conductor **202***x*. The signal input terminal **82***x* is connected to the connection terminal **56***gx* in the upper portion of the coupling conductor **51***gax* of the directional coupler **50***gx* through a connection strip conductor **203***x* having a zigzag shape. The connection terminal **57***gx* on the lower portion of the coupling conductor **51***gax* of the directional coupler **50***gx* is connected to the signal output terminal **90***x* through the connection strip conductor **204***x*. The signal input terminal **83***x* is connected to the connection terminal **57***ex* in the lower portion of the coupling conductor **51***eax* of the directional coupler **50***ex* through a connection strip conductor **205***x* having a zigzag shape. The connection terminal **56***ex* in the upper portion of the coupling conductor **51***eax* of the directional coupler **50***ex* is connected to the signal output terminal **91***x* through the connection strip conductor **206***x*. The signal input terminal **84***x* is connected to the connection terminal **57***fx* in the lower portion of the coupling conductor **51***fax* of the directional coupler **50***fx* through a connection strip conductor **207***x*. The connection terminal **56***fx* on the upper portion of the coupling conductor **51***fax* of the directional coupler **50***fx* is connected to the signal output terminal **92***x* through the connection strip conductor **208***x*.

As shown in FIG. 7(C), on the lower surface of the dielectric substrate **10***bx*, the signal input terminal **85***x* is connected to the connection terminal **58***fx* in the upper portion of the coupling conductor **51***fbx* of the directional coupler **50***x* through a connection strip conductor **209***x*. The connection terminal **59***fx* in the lower portion of the coupling conductor **51***fbx* of the directional coupler **50***fx* is connected to the signal output terminal **93***x* through the connection strip conductor **210***x*. The signal input terminal **86***x* is connected to the connection terminal **58***ex* in the upper portion of the coupling conductor **51***ebx* of the directional coupler **50***ex* through a connection strip conductor **211***x*. The connection terminal **59***ex* on the lower portion of the coupling conductor **51***ebx* of the directional coupler **50***ex* is connected to the signal output terminal **94***x* through the connection strip conductor **212***x*. The signal input terminal **87***x* is connected to the connection terminal **59gx** in the lower portion of the coupling conductor **51gbx** of the directional coupler **50gx** through a connection strip conductor **213x** having a zigzag shape. The connection terminal **58gx** on the upper portion of the coupling conductor **51gbx** of the directional coupler **50gx** is connected to the signal output terminal **95x** through the connection strip conductor **214x**. The signal input terminal **88x** is connected to the connection terminal **59hx** in the lower portion of the coupling conductor **51hbx** of the directional coupler **50hx** through a connection strip conductor **25x** having a zigzag shape. The connection terminal **58hx** in the upper portion of the coupling conductor **51hbx** of the directional coupler **50hx** is connected to the signal output terminal **96x** through the connection strip conductor **216x**.

The width of the respective connection strip conductors **201x** to **216x** is determined corresponding to the characteristic impedance.

It is noted that the respective signal input terminals **81x** to **84x** and the signal output terminals **89x** to **96x** are formed alternatively on the dielectric substrates **10ax** and **10bx** as shown in FIGS. 7(A) and 7(C) with the different positions on one side of the dielectric substrates **10ax** and **10bx**. Accordingly, when connecting the lead wires to the signal input and output terminals **81x** and **96x**, the connection points do not overlap and the connection of the lead wires is easy.

In order to output the signal corresponding to the input signal applied to the signal input terminals **81x** to **88x** at the respective output terminals **89x** to **96x** with the same phase difference, the electric length of the connection strip conductor begins from the respective signal input terminals **81x** to **88x** and ends at the signal output terminals **89x** to **96x** through the respective directional couplers. That is, the total electric length of the connection strip conductors **201x** and **202x** includes the total electric length of the connection strip conductors **203x** and **204x**; the total electric length of the connection strip conductors **205x** and **206x** and the total electric length of the connection strip conductors **207x** and **208x** being uniform. The total electric length of the connection strip conductors **209x** and **210x** includes the total electric length of the connection strip conductors **211x** and **212x**, the total electric length of the connection strip conductors **213x** and **214x** and the total electric length of the connection strip conductors **215x** and **216x** being uniform.

The directional coupler **80x** mentioned above is connected to the multi terminal directional couplers **60x** and **60'x** formed integrally. It is possible to provide the 8 input and 8 output multi terminal directional coupler **118x** as shown in FIG. 12 and the directional coupler **80x** operates similar to the known multi terminal directional coupler **120x** of FIG. 12. The multi terminal directional coupler **120x** is a reversible circuit similar to the multiple directional coupler **60x**. The multi terminal directional coupler arranged using the directional couplers **50ax** to **50hx** has the same advantage as the multi terminal directional coupler **60x** of FIGS. 5(A) to 5(B). Although, in the embodiments of FIGS. 7 and 9, the respective directional couplers **50ex** and **50fx** are located at positions as shown in FIG. 9, the directional coupler **50ex** may be located at the solid crossing portion between the input terminals **83x** and **86x** and the output terminals **91x** and **94x**. That is, the directional coupler **50ex** may be located at the position of the directional coupler **50ex** as presently shown in FIG. 9 or at a position **302x** where the connection strip conductors **206x** and **212x** cross in a solid manner. Also, the directional coupler **50fx** may be located at the solid crossing portion between the input terminals **84x** and **85x** and the output terminals **92x** and **93x**. That is, at a position where the connection strip conductors **208x** and **210x** cross a solid manner. In addition, the directional couplers **50ex** and **50fx** may be located at any one of four positions mentioned below.

(1) The directional coupler **50ex** is located at a position **303x** where the connection strip conductors **206x** and **209x** cross in a solid manner. The directional coupler **50fx** is located at a position **304x** where the connection strip conductors **207x** and **212x** cross in a solid manner.

(2) The directional coupler **50ex** is located at a position **305x** where the connection strip conductors **206x** and **210x** cross in a solid manner. The directional coupler **50fx** is located at a position **306x** where the connection strip conductors **208x** and **212x** cross in a solid manner.

(3) The directional coupler **50ex** is located at a position **303x** and the directional coupler **50fx** is located at a position **306x**.

(4) The directional coupler **50ex** is located at a position **304x** and the directional coupler **50fx** is located at a position **305x**.

Although, in the embodiments of FIGS. **7** and **9**, the respective directional couplers **50gx** and **50hx** are located at positions as shown in FIG. **9**, the directional coupler **50gx** may be located at the solid crossing portion **307x** where the connection strip conductors **201x** and **214x** cross in a solid manner. The directional coupler **50hx** may be located at the solid crossing position **308x** where the connection strip conductors **204x** and **215x** cross in a solid manner.

Although the embodiment is explained with respect to the directional coupler having four or eight input and output terminals, the present invention is not limited to this embodiment. For example, the present invention may be applied to a multi terminal directional coupler having more than 16 terminals. In general, the present invention may be applied to a multi terminal directional coupler comprising:

first input terminals with the number of terminals being N/2 wherein N is 2^n (n is natural number) and N/2 first output terminals being respectively juxtaposed on one side of the ground conductor through the first dielectric substrate;

N/2 second input terminals and N/2 second output terminals being juxtaposed on another side of the ground conductor through the second dielectric substrate;

the first multi terminal directional coupler comprising $n \times 2^{n-1}$ directional couplers formed on the first dielectric substrate and connected to the N/4 first input terminals and the N/4 second input terminals, the N/4 third output terminals formed on the first dielectric substrate and the N/4 fourth output terminals formed on the second dielectric substrate;

the second multi terminal directional coupler including $n \times 2^{n-1}$ directional couplers formed on the first dielectric substrate and connected to the N/4 first input terminals and the N/4 second input terminals, the N/4 fifth output terminals formed on the second dielectric substrate and the N/4 sixth output terminals formed on the second dielectric substrate;

N/4 first directional couplers connected to either one of the N/4 third output terminals of the first multi terminal directional coupler and one of the N/4 sixth output terminals of the second multi terminal directional couplers without overlapping each other and connected to either one of the N/4 first output terminals and one of the N/4 second output terminals without overlapping each other; and

N/4 second directional couplers connected to either one of the N/4 fourth output terminals of the first multi terminal directional coupler and one of the N/4 fifth output terminals of the second multi terminal directional couplers without overlapping each other and connected to either one of the N/4 first output terminals and one of the N/4 second output terminals without overlapping each other;

whereby the first multi terminal directional coupler, the second multi terminal directional coupler, the N/4 first directional couplers and the N/4 second directional couplers and two coupling conductors in which the respective opposite ends form the input terminals and the output terminals are formed on both sides of the ground conductor through the first dielectric substrate and the second substrate, so that the respective coupling conductors are coupled electromagnetically through the opening defined in the ground conductor.

In the present embodiment, the respective coupling conductors **51***aax*, **51***abx*, **51***bax*, **51***bbx*, **51***cax*, **51***cbx*, **51***dax*, **51***dbx*, **51***eax*, **51***ebx*, **51***fax*, **51***fbx*, **51***gax*, **51***gbx*, **51***hax* and **51***hbx* and the coupling openings **52***ax* to **52***hx* are elongated in rectangular shape. The shape of the conductors may be selected as desired so far as there are formed openings in the ground conductor **11***x* between the respective pairs of conductors **51***aax* and **51***abx*; **51***bax* and **51***bbx*; **51***cax* and **51***cbx*; **51***dax* and **51***dbx*; **51***eax*, **51***ebx*; **51***fax* and **51***fbx*; **51***gax* and **51***gbx* and **51***hax*, **51***hbx* so that electromagnetic mode coupling is formed between the pairs of the coupling conductors.

As mentioned above, in the present invention, there are provided N input and output terminals (wherein N is 2^l (l is a natural number)) and $l \times 2^{l-1}$ directional couplers so that signals having a/N power of the input signals applied to the N input terminals can be output at the N output terminals. The respective $l \times 2^{l-1}$ directional couplers are formed on both sides of the ground conductor through the first and second dielectric substrates with the two coupling conductors having their opposite ends forming input and output terminals so that the respective coupling conductors can be electromagnetically coupled through the opening defined on the ground conductor formed therebetween. Therefore, the input terminals, the output terminals, the coupling conductors of the respective directional couplers and the strip conductors for connecting the respective terminals and coupling conductors may be formed by dividing the two dielectric substrates into two parts formed on both sides of the ground conductor. Accordingly, the size of the multi terminal directional coupler becomes ⅜ as compared to a conventional directional coupler so that it is possible to decrease the size and weight. By the arrangement mentioned above, the multi terminal directional coupler can be formed without a solid crossing. Therefore, it is possible to form the circuit patterns accurately and to prevent the interference among the signals propagating in the strip conductors. Therefore, it is possible to provide a multi terminal directional coupler in which the power of the signals can be divided and good electric property is provided.

Referring to FIGS. **15**(A) to **15**(E) which shows a further embodiment of the present invention, there are defined coupling openings **22***ay* and **22***by* which penetrate a ground conductor **12***y* and have a length on the short side and a length λg/4 on the long side in the upper right portion and the lower right portion of an elongated ground conductor **12***y* having a thickness t0. The coupling openings **232***ay* and **22***by* are filled with coupling insulation materials **10***cay* and **10***cdy*. The ground conductor **12***y* is provided between dielectric substrates **10***ay* and **10***by* which have a thickness of t.

In the upper left portion of FIG. **15**(A) above the dielectric substrate **10***ay*, a coupling conductor **21***aay* of a rectangular shape having a length S on the short side and a length λg/4 on the long side is formed above the coupling insulation material **10***cay*. On the other hand, another coupling conductor **21***aby*, which is similar to the conductor **21***aay*, is formed below the coupling insulation material **10***cay* on the central left portion of FIG. **15**(C) on the lower surface of the dielectric substrate **10***by*. The coupling conductors **21***aay* and **21***aby* are so formed that the longitudinal direction of the coupling conductors **21***aay* and **21***aby* is parallel to the respective short sides of the dielectric substrate **10***ay* and **10***by*. When the microwave signals are applied to the ends of the short sides of the coupling conductors **21***aay* and **21***aby*, mode coupling is developed between the coupling conductors **21***aay* and **21***aby* and the ground conductor **12***y* through the coupling insulation material **10***cay* in the coupling opening **22***ay* so that the power of the signal is divided into two parts. The divided signals are input to another terminal and the signals are coupled with the other divided signal and the coupled signals can be output on the respective ends of the short sides of the coupling conductors **21***aay* and **21***aby*. In FIG. **15**(A), the dotted lines indicate the position of the coupling openings **22***ay* and **22***by*. In one directional coupler **20***ay*, the respective short sides of the coupling opening **22***ay* of the ground conductor **12***y* and the short sides of the coupling conductors **21***ay* and **21***aby* coincide with each other. The dielectric substrates **10***ay* and **10***by* and the coupling insulation material **10***cay* are made of dielectric material having the same dielectric constant. The directional coupler **20***by* is formed in the same manner as mentioned above.

FIGS. **16**(A) and **16**(B) are respectively vertical cross sectional views showing the electric field distribution of odd and even modes by a known vertical mode driving at the coupling portion on the B—B′ line in FIG. **15**. In the even mode of FIG. **16**(A), there are developed electric force lines between the connecting conductors **21***aay* and **21***aby* and the ground conductor **12***y*, whereby the opening acts as a magnetic wall. On the other hand, in the odd mode of FIG. **16**(B), there are developed electric force lines between the connecting conductors **21***aay* and **21***aby* and the ground conductor **12***y*, whereby the opening acts as an electric wall.

Accordingly, there is formed a directional coupler **20***ay* having a predetermined coupling degree by the ground conductor **12***y* and the connecting conductors **21***aay* and **21***aby* formed on the dielectric substrate **10***ay* and **10***by*. Therefore, there can be provided a four terminal directional coupler **20***ay* having a coupling degree of 3 dB by selecting the dielectric constant of the dielectric substrates **10***ay* and **10***by*, the width of S of the connecting conductors **21***aay* and **21***aby* and the width W of the coupling opening 22*ay*. It is noted that the coupling degree is 3 dB. In order to increase the coupling degree, the width W of the coupling opening 22*ay* is made large.

There is formed a coupling conductor 21*bay* having the same shape of the conductor 21*aay* directly above the coupling insulation material 10*cby* at the central right portion of FIG. 15(A) on the dielectric substrate 10*ay*. A connecting conductor 21*bby* having the same shape of the conductor 21*aby* is formed directly below the coupling insulation material 10*cby* at the central left portion of FIG. 15(B) on the lower surface of the dielectric substrate 10*by*. Accordingly, there can be provided a directional coupler 20*by* having a 3 dB coupling degree in a similar manner as the directional coupler 20*ay* by the ground conductor 12*y* and the connecting conductors 21*bay* and 21*bby*.

A hybrid amplifier 5*y* having a known structure with a predetermined amplification factor is formed at the central portion of the upper surface of the dielectric substrate 10*ay*. A hybrid amplifier 6*y* having a known structure with a predetermined amplification factor is formed at the central portion of the lower surface of the dielectric substrate 10*by*.

In the upper surface of the dielectric substrate 10*ay*, the signal input terminal 1*y* is connected to the connection terminal 23*ay* in the upper portion of the coupling conductor 21*aay* of the directional coupler 20*ay* through a connection strip conductor 131*y*. The connection terminal 24*ay* in the lower portion of the coupling conductor 21*aay* of the directional coupler 20*ay* is connected to the signal input terminal 5*ay* of the amplifier 5*y* through the connection strip conductor 133*y*. The output terminal 5*by* of the amplifier 5*y* is connected to the connection terminal 23*by* in the upper portion of the coupling conductor 21*bay* of the directional coupler 20*by* through a connection strip conductor 135*y*. The connection terminal 24*by* in the lower portion of the coupling conductor 21*bay* of the directional coupler 20*by* is connected to the non reflective terminating device 8*y* through the connection strip conductor 138*y*.

In the lower surface of the dielectric substrate 10*by*, the connection terminal 26*ay* in the lower portion of the connection conductor 21*aby* of the directional coupler 20*ay* is connected to a non reflective terminating device 7*y* through the connection strip conductor 132*y*. The connection terminal 25*ay* in the upper portion of the connection conductor 21*aby* of the directional coupler 20*ay* is connected to the amplifier 6*y* through the connection strip conductors 134*y*. The output terminal 6*by* of the amplifier 6*y* is connected to a connection terminal 26*by* in the lower portion of the connection conductor 21*bby* of the directional coupler 20*by* through the connection strip conductor 136*y*. The connection terminal 25*by* for the connection conductor 21*bby* of the directional coupler 20*by* is connected to the signal output terminal 2*y* through the connection strip conductors 137*y*.

The connection strip conductors 131*y* to 138*y* have respectively desired widths which are defined by the characteristic impedance.

In order to match the impedance of the signal input terminal 1*y* and the signal output terminal 2*y*, two amplifiers 5*y* and 6*y* have the same input and output impedance and the same amplification and gain properties.

The microwave signal entered in the signal input terminal 1*y* is input to the connection terminal 23*ay* of the directional coupler 20*ay*, in which the input signal is divided in two parts. One part of the divided signal is entered to the input terminal 5*ay* of the amplifier 5*y* through the connection terminal 24*ay* situated on the same plane of the connection terminal 23*ay* and further through the strip conductor 133*y*. Another part of the divided signal that is divided by the directional coupler 20*ay* is entered to the input terminal 6*ay* of the amplifier 6*y* through the connection terminal 25*ay* which is located on a plane opposite to the plane having the connection terminal 23*ay* located thereon and further through the connection strip conductor 134*y*. The respective signals output from the output terminal 5*by* of the amplifier 5*y* and the output terminal 6*by* of the amplifier 6*y* are respectively input to the connection terminals 23*by* and 26*by* of the directional coupler 20*by* through the connection strip conductors 135*y* and 136*y*. The respective signals input to the directional coupler 20*by* are composed or coupled and the composed signals are output at the signal output terminal 2*y* through the connection terminal 25*by* and the connection strip conductor 137*y*.

In the microwave balanced amplifier mentioned above, two amplifiers 5*y* and 6*y* are located on the dielectric substrates 10*ay* and 10*by*. Since the two amplifiers are separated by the ground conductor, interference does not occur for the signals from the amplifiers 5*y* and 6*y*. Accordingly, the signal entered into the signal input terminal 1*y* can be processed having good electrical properties. Moreover, because two amplifiers 5*y* and 6*y* and the connection strip conductors are located on both sides of the dielectric substrates 10*ay* and 10*by*, it is possible to decrease the size of the microwave balanced amplifier about ½ of the size of the conventional device. Thereby, the weight of the amplifier device is reduced. Moreover, in the present embodiment it is not necessary to couple the signals by way of ridge coupling using wire or ribbon conductors as employed in the interdigit directional coupler. Whereby, the circuit patterns can be accurately formed and the production of the device in present embodiment is more simple than the production of a conventional device. In addition, since the conductor patterns of the dielectric substrate 10*ay* of FIG. 15(A) is the same as the conductor patterns on the dielectric substrate 10*by* of FIG. 15(C), it is advantageous for the two conductor patterns to be produced using the same pattern.

FIG. 17 is a circuit diagram showing an embodiment of the four input and four output multi terminal amplifier according to the present invention.

In FIG. 17, four amplifiers 31*y* to 34*y* are connected between the first and second multi terminal directional couplers 201*y* and 202*y*, each coupler has four inputs and four outputs. The multi terminal directional couplers 201*y* and 202*y* include four directional couplers 40*ay* to 40*dy* and 40*ey* to 40*hy* each having a 3 dB coupling degree. Whereby, four output signals each having ¼ power of the input signals applied to the four input terminals can be output at the four output terminals. Accordingly, by changing the amplification factor of the amplifiers 31*y* to 34*y*, there can be obtained at the output terminals 55*y* to 58*y* the output signals each having a desired power level which have been coupled from the input signals entered at the input terminals 51*y* to 54*y* with a predetermined power level and then amplified.

FIGS. 18(A) to 18(C) are circuit diagrams showing a specific structure of the multi terminal amplifier of FIG. 17, FIG. 18(A) is a top plan view of the multi terminal amplifier, FIG. 18(B) is a plan view showing the ground conductor **12**_y_ of the multi terminal amplifier of FIG. 18(A) and FIG. 18(C) is a plan view showing conductor patterns on the dielectric substrate **10**_by_ of the multi terminal amplifier of FIG. 18(A). In FIGS. 18(A) to 18(C), like parts are designated with like reference numerals The multi terminal amplifier includes a first directional coupler **201**_y_ having four directional couplers **40**_ay_ to **40**_dy_, an amplifier formed by four amplifiers **31**_y_ to **34**_y_ and a second multi terminal directional coupler **202**_y_ having four directional couplers **40**_ey_ to **40**_hy_.

In FIG. 18(A), there are defined coupling openings **42**_ay_ to **42**_dy_ which penetrate a ground conductor **12**_y_ and have a length W on the short side and a length λg/4 on the long side in the upper left portion, the lower left portion, the central portion and the central right portion of the multi terminal directional coupler **201**_y_ of an elongated ground conductor **12**_y_ having a thickness of t0. The coupling openings **42**_ay_ to **42**_dy_ are filled by coupling insulation materials **10**_cay_ and **10**_cby_, **10**_ccy_ and **10**_cdy_. In the left central portion, the right central portion, the upper right portion and the lower right portion of the multi terminal directional coupler **202**_y_ of the ground conductor **12**_y_, there are defined coupling openings **42**_ey_ to **42**_hy_ penetrating the ground conductor **12**_y_ with short sides having a length of W and long sides having a length of λg/4. The respective coupling openings are filled by the coupling insulation materials **10**_cey_, **10**_cfy_, **10**_cgy_ and **10**_chy_. The ground conductor **12**_y_ is provided between two dielectric substrates **10**_ay_ and **10**_by_.

On the top surface of the dielectric substrate **10**_ay_, there are formed rectangular coupling conductors **41**_aay_, **41**_bay_, **41**_cay_, **41**_day_, **41**_eay_, **41**_fay_, **41**_gay_ and **41**_hay_ each having short sides of a length S and long sides of a length λg/4. On the lower surface of the dielectric substrate **10**_by_ of FIG. 18(C), coupling conductors **41**_aby_, **41**_bby_, **41**_cby_, **41**_dby_, **41**_eby_, **41**_fby_, **41**_gby_, and **41**_hby_ having the same shape as the conductor **41**_aay_ are respectively formed directly below the coupling insulation materials **10**_cay_ to **10**_chy_. The respective input terminals and output terminals of the multi terminal amplifier are formed on one side of the multi terminal amplifier. In order to form the same electric length between the respective input terminals and output terminals, the coupling conductors **41**_aay_ to **41**_hay_ and **41**_aby_ to **41**_hby_ are formed in such a manner that the longitudinal direction of the conductors **41**_aay_ to **41**_hay_ and **41**_aby_ to **41**_hby_ are in a parallel direction to the short side of the dielectric substrates **10**_ay_ and **10**_by_.

Accordingly, similar to the directional couplers **20**_ay_ and **20**_by_, there is formed a directional coupler **40**_ay_ having a 3 dB coupling degree by the coupling conductors **41**_aay_ and **41**_by_ and the ground conductor **12**_y_. In a similar manner, there are formed directional couplers **40**_by_ to **40**_hy_ having a 3 dB coupling degree.

On the top surface of the dielectric substrate **10**_ay_, the signal input terminal **51**_y_ is connected to the connection terminal **43**_ay_ in the upper portion of the coupling conductor **41**_aay_ of the directional coupler **40**_ay_ through a connection strip conductor **61**_y_. The connection terminal **44**_ay_ in the lower portion of the coupling conductor **41**_aay_ of the directional coupler **40**_ay_ is connected to the connection terminal **43**_cy_ in the upper portion of the coupling conductor **41**_cay_ of the directional coupler **40**_cy_ through the connection strip conductor **62**_y_ which has an S shape. The connection terminal **44**_cy_ in the lower portion of the coupling conductor **41**_cay_ of the directional coupler **40**_cy_ is connected to the input terminal **31**_ay_ of the amplifier **31**_y_ through a connection strip conductor **63**_y_. The signal input terminal **53**_y_ is connected to the connection terminal **43**_by_ in the upper portion of the coupling conductor **41**_bay_ of the directional coupler **40**_by_ through the connection strip conductor **67**_y_. The connection terminal **44**_by_ in the lower portion of the coupling conductor **41**_bay_ of the directional coupler **40**_by_ is connected to the connection terminal **44**_by_ in the lower portion of the coupling conductor **41**_day_ of the directional coupler **40**_day_ through the connection strip conductor **68**_y_ which has a zigzag shape. The connection terminal **43**_by_ in the upper portion of the coupling conductor **41**_day_ of the directional coupler **40**_by_ is connected to the input terminal **32**_ay_ of the amplifier **32**_y_ through the connection strip conductor **69**_y_.

The output terminal **31**_by_ of the amplifier **31**_y_ is connected to the connection terminal **44**_ey_ in the lower portion of the coupling conductor **41**_eay_ of the directional coupler **40**_ey_ through the connection strip conductor **64**_y_. The connection terminal **43**_ey_ in the upper portion of the coupling conductor **41**_eay_ of the directional coupler **40**_ey_ is connected to the connection terminal **43**_gy_ in the upper portion of the coupling conductor **41**_gay_ of the directional coupler **40**_gy_ through the connection strip conductor **65**_y_ which has a zigzag shape. The connection terminal **44**_gy_ in the lower portion of the coupling conductor **41**_gay_ of the directional coupler **40**_gy_ is connected to the signal output terminal **55**_y_ through the connection strip conductor **66**_y_. The output terminal **32**_by_ of the amplifier **32**_y_ is connected to the connection terminal **43**_fy_ in the upper portion of the coupling conductor **41**_fay_ of the directional coupler **40**_fy_ through the connection strip conductor **70**_y_. The connection terminal **44**_fy_ in the lower portion of the coupling conductor **41**_fay_ of the directional coupler **40**_f_ is connected to the connection terminal **43**_hy_ on the upper portion of the coupling conductor **41**_hay_ of the directional coupler **40**_hy_ through the connection strip conductor **71**_y_ which has an S shape. The connection terminal **44**_hy_ in the lower portion of the coupling conductor **41**_hay_ of the directional coupler **40**_hy_ is connected to the signal output terminal **56**_y_ through the connection strip conductor **72**_y_.

On the lower surface of the dielectric substrate **10**_by_, the signal input terminal **52**_y_ is connected to the connection terminal **46**_ay_ in the lower portion of the coup ling conductor **41**_aby_ of the directional coupler **40**_ay_ through a connection strip conductor **73**_y_. The connection terminal **45**_ay_ on the upper portion of the coupling conductor **41**_aby_ of the directional coupler **40**_ay_ is connected to the connection terminal **45**_dy_ in the upper portion of the coupling conductor **41**_dby_ of the directional coupler **40**_dy_ through the connection strip conductor **74**_y_ which has a zigzag shape. The connection terminal **46**_dy_ in the lower portion of the coupling conductor **41**_dby_ of the directional coupler **40**_dy_ is connected to the input terminal **33**_ay_ of the amplifier **33**_y_ through a connection strip conductor **75**_y_. The signal input terminal **54**_y_ is connected to the connection terminal **46**_by_ in the lower portion of the coupling conductor **41**_bby_ of the directional coupler **40**_by_ through the connection strip conductor **79**_y_. The connection terminal **45**_by_ in the upper portion of the coupling conductor **41**_bby_ of the directional coupler **40**_by_ is connected to the connection terminal **46**_cy_ in the lower portion of the coupling conductor **41**_cdy_ of the directional coupler **40**_cy_ through the connection strip conductor **80**_y_ which has an S shape. The connection terminal **45**cy in the upper portion of the coupling conductor **41**cby of the directional coupler **40**cy is connected to the input terminal **34**ay of the amplifier **34**y through the connection strip conductor **81**y.

The output terminal **33**by of the amplifier **33**y is connected to the connection terminal **46**fy in the lower portion of the coupling conductor **41**fby of the directional coupler **40**fy through the connection strip conductor **76**y. The connection terminal **45**fy in the upper portion of the coupling conductor **41**fby of the direction coupler **40**fy is connected to the connection terminal **46**gy in the lower portion of the coupling conductor **41**gby of the directional coupler **40**gy through the connection strip conductor **77**y which has an S shape. The connection terminal **45**gy in the upper portion of the coupling conductor **41**gby of the directional coupler **40**gy is connected to the signal output terminal **57**y through the connection strip conductor **78**y. The output terminal **34**by of the amplifier **34**y is connected to the connection terminal **45**ey in the upper portion of the coupling conductor **41**eby of the directional coupler **40**ey through the connection strip conductor **82**y. The connection terminal **46**ey in the lower portion of the coupling conductor **41**eby of the directional coupler **40**ey is connected to the connection terminal **46**hy in the lower portion of the coupling conductor **41**hby of the directional coupler **40**hy through the connection strip conductor **83**y which has a zigzag shape. The connection terminal **45**hy in the upper portion of the coupling conductor **41**hby of the directional coupler **40**hy is connected to the signal output terminal **58**y through the connection strip conductor **84**y.

The widths of the connection strip conductors **61**y and **84**y are determined by the characteristic impedance corresponding thereto.

The signals entered to the signal input terminals **51**y to **54**y are processed in the multi terminal amplifiers of FIGS. **18**(A) and **18**(C). In order to output the processed signals to the signal output terminals **55**y to **58**y with the same phase difference against the input signals, the electric length of the connection strip conductor begin from the respective signal input terminals **51**y to **54**y and end at the signal output terminals **55**yx to **58**y through the respective directional couplers and the amplifiers. That is, the electric length includes the total electric length of the connection strip conductors **61**y and **66**y; the total electric length of the connection strip conductors **67**y to **72**y; the total electric length of the connection strip conductors **73**y to **78**y; and the total electric length of the connection strip conductors **79**y to **84**y which are made uniform.

The multi terminal directional coupler arranged as mentioned above is equivalent to the circuit of FIG. **17**. By changing the amplification factors of the amplifiers **31**y to **34**y, it is possible to obtain the coupled and amplified signals having a desired power level at the signal output terminals **55**y to **58**y from the signal input at the signal input terminals **51**y to **54**y which are coupled with the same degree.

As mentioned above, since the signal input terminals **51**y to **54**y, the signal output terminals **55**y to **58**y, the amplifiers **31**y to **34**y and the connection strip conductors **61**y to **84**y for connecting the respective terminals are divided in two parts on both sides of the dielectric substrates **10**ay and **10**by employing the directional couplers **40**ay to **40**hy in place of using the interdigit directional coupler, and the size of the four input or output multi terminal amplifier may be decreased to ½ of the conventional multi terminal amplifier using the inter digit directional coupler. In the present embodiment, since it is not necessary to provide a ridge coupling by the wire or ribbon conductor as used in the inter digit directional coupler, the circuit patterns can be accurately made and the manufacturing for the present device is easier than the manufacturing for the conventional device. The conductor patterns on the dielectric substrate **10**ay of FIG. **18**(A) are the same as the patterns which are rotated by 180° from the patterns of the dielectric substrate **10**by of FIG. **18**(C) around the center of the dielectric substrate **10**by, whereby the respective conduction patterns can be made by the same pattern.

Although in the present embodiment, the hybrid amplifiers **5**y, **6**y and **31**y to **34**y are formed on the dielectric substrates **10**ay and **10**by, the present invention is not limited to this embodiment. It may be possible to replace the dielectric substrates by semiconductor substrates and the hybrid amplifiers **5**y, **6**y and **31**y to **34**y may be replaced by various types of amplifiers such as a MMIC formed on the semiconductor substrate. In this case, the coupling insulation material may be replaced by a semiconductor material.

Although the coupling conductors **21**aay, **21**aby, **21**day, **21**bby, **41**aay, **41**$abyu$, **41**bay, **41**bby, **41**cay, **41**cby, **41**day, **41**dby, **41**eay, **41**eby, **41**fay, **41**fby, **41**gay, **41**gby, **41**hay and **41**hby and coupling openings **22**ay, **22**by and **42**ay to **42**hy are respectively formed of a rectangular shape, the shape is not limited to a rectangular shape, provided that openings are formed between the coupling conductors of the directional coupler so that the mode coupling can be electromagnetically developed between each pair of the coupling conductors.

Although the explanation is made with respect to a device having four signal input and output terminals, more than 16 multi terminals may be used in the device of the present invention.

In place of the amplifiers **5**y, **6**y and **31**y and **34**y, various microwave signal processing devices such as an attenuator, a phase shifter, a modulator and/or a frequency converter may be used. Accordingly, in the present invention by providing at least one of the directional couplers **50**ay and **50**by the microwave signal processing device may be provided in the present invention, so that the present invention can be applied to the various types of microwave devices. Accordingly, it is possible to provide microwave devices which are able to process input signals having a good electric property for preventing the interference between the signals propagating in the lines with the microwave devices being small in size, light in weight and capable of easy manufacturing.

In a case where the phase shifters are used in place of the amplifiers **5**y and **6**y of FIGS. **15**(A) and **15**(C), by changing the amount of phase shift in the phase shifters, it is possible to take attenuated microwave signals from the output terminals **2**y using the input microwave signals at the input terminal **1**y.

In the present invention, since there are provided one or more directional couplers formed in such a manner that two coupling conductors forming input and output terminals are disposed on both sides of the ground conductor through the substrates so that the coupling conductors can be electromagnetically coupled through openings defined in the ground conductor between the coupling conductors and microwave signal processing device disposed in the front stage or the rear stage of the directional coupler. The coupling conductors of the directional coupler, the microwave signal processing device and various lines for connecting the coupling conductors and the microwave processing device may be formed on both sides of the two substrates that are separated into two parts. Accordingly the size of the microwave device is about ½ of the conventional device and it is possible to provide a light and small sized device. Since the device according to the present invention can be provided without using wire and ribbon coupling conductors to develop the ridge coupling, the interference among the signals can be prevented. Therefore, a microwave device can be provided which is able to process the microwave signal having a good electric property.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

We claim:

1. A multi-terminal directional coupler device, comprising:

a ground conductor having a top surface, a bottom surface, and a plurality of openings formed therein;

a coupling insulation material formed in said plurality of openings;

first and second dielectric substrates formed on said top and bottom surfaces, respectively;

a plurality of first directional couplers formed by said coupling insulation material in said plurality of openings for electromagnetic coupling signals;

a plurality of pairs of coupling conductors disposed on said first and second dielectric substrates, respectively, said plurality of pairs of coupling conductors being disposed adjacent to said plurality of openings; and

a plurality of second branch line couplers disposed on said first and second dielectric substrates, said plurality of second branch line couplers being connected to said plurality of pairs of coupling conductors.

2. A coupler device as claimed in claim 1, wherein said plurality of openings are formed in a rectangular shape and said plurality of pairs of coupling conductors are substantially formed in said rectangular shape.

3. A multi-terminal directional coupler device, comprising:

a ground conductor having a top surface, a bottom surface, and a plurality of openings formed therein;

a coupling insulation material formed in said plurality of openings;

first and second dielectric substrates formed on said top and bottom surfaces, respectively;

a plurality of directional couplers formed by said coupling insulation material over said plurality of openings for electromagnetic coupling signals;

a plurality of pairs of coupling conductors disposed on said first and second dielectric substrates, respectively, said plurality of pairs of coupling conductors being disposed adjacent to said plurality of openings;

a predetermined number of input and output terminals disposed on said first and second dielectric substrates and connected to said plurality of pairs of coupling conductors, said predetermined number of input and output terminals being equal to 2^l, where l is a natural number greater than or equal to 2, and said plurality of directional couplers are equal to l. 2^{l-1}, and outputting signals to said predetermined number of output terminals having ½ of the power of signals inputted from said predetermined number of input terminals.

4. A microwave device comprising:

a ground conductor having a top surface, a bottom surface, and a predetermined number of openings formed therein;

a coupling insulation material formed in said predetermined number of openings;

first and second dielectric substrates formed on said top and bottom surfaces, respectively;

directional couplers, of said predetermined number, formed by said coupling material over said predetermined number of openings for electromagnetic coupling signals;

first coupling conductors, of said predetermined number, disposed over said predetermined number of said directional couplers on said first dielectric substrate, said predetermined number of said first coupling conductors being patterned for connecting said directional couplers thereto;

second coupling, of said predetermined number, conductors disposed over said predetermined number of said directional couplers on said second dielectric substrate, said predetermined number of said second coupling conductors being patterned for connecting said directional couplers;

first microwave signal processing means disposed on said first dielectric substrate, an input of said first microwave signal processing means being connected to one of said predetermined number of said first coupling conductors and an output of said first microwave signal processing means being connected to another of said predetermined number of said first coupling conductors; and

second microwave signal processing means disposed on said second dielectric substrate, an input of said second microwave signal processing means being connected to one of said predetermined number of said second coupling conductors and an output of said second microwave signal processing means being connected to another of said second coupling conductors.

5. A microwave device as claimed in claim 4, wherein said first and second microwave signal processing means comprise first and second amplifiers.

6. A method for forming a multi-terminal directional coupler device, comprising the steps of:

forming a ground conductor having a top surface and a bottom surface;

forming a predetermined number of openings in said ground conductor;

disposing a coupling insulation material in said predetermined number of openings;

disposing first and second dielectric substrates on said top and bottom surfaces, respectively;

forming directional couplers of said predetermined number corresponding to said coupling insulation material over said predetermined number of openings for electromagnetic coupling signals;

disposing pairs of coupling conductors of said predetermined number on said first and second dielectric substrates, respectively, adjacent to said predetermined number of openings; and

connecting said predetermined number of said pairs of coupling conductors on said first and second dielectric substrates, respectively.

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